MISSILES, ROCKETS AND NUCLEAR WEAPONS

US ARMY

В. М. ГЛУСКИН

РАКЕТНО-ЯДЕРНОЕ ОРУЖИЕ АРМИИ США

(на английском языке)

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МИНИСТЕРСТВА ОБОРОНЫ СССР
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Владимир Маркович Глускин

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ОТ АВТОРА

Книга «Ракетно-ядерное оружие армии США» (на английском языке) имеет целью познакомить читателя с основной терминологией по затрагиваемой тематике и сообщить ему некоторые сведения о ракетно-ядерном оружии США и его боевом использовании.

Материал в книге расположен по тематическому принципу и разбит на три части. В первой части рассматриваются общие принципы действия ракетного двигателя, дается описание устройства современных ракет вообще и основных видов ракетных систем США в частности. Вторая часть содержит популярное изложение теории строения атома и основ ядерных реакций деления и синтеза. В ней также подробно излагается действие и поражающие факторы ядерного взрыва и меры защиты от них. В третьей части излагаются американские взгляды на особенности боевых действий в условиях применения ядерного оружия и порядок его боевого использования.

В книге приводятся тактико-технические характеристики различных видов ракетно-ядерного оружия США, образцы боевых документов и различных расчетных таблиц.

В книгу включены также краткие толковые словари (Glossaries). Как и вся книга, они составлены по тематическому принципу. *Glossary, Division One* содержит лексику, относящуюся к ракетному оружию (часть I), *Glossary, Division Two* — лексику, относящуюся к ядерному оружию и его боевому применению (части II и III). В словарях дается толкование наиболее важных терминов на английском языке и их перевод на русский язык.

Книга имеет подробное оглавление как на английском, так и на русском языке.

Материалы книги взяты из зарубежных (в основном американских) источников. В книге полностью, без каких-либо изменений, сохранена принятая в США трактовка и оценка затрагиваемых вопросов. Все характеристики существующих боевых систем и ядерных устройств, равно как технических решений и оперативно-тактических положений, даны в той формулировке, в которой они приводятся в зарубежных источниках. Тактико-технические характеристики ракетных систем даны по американскому журналу *Missiles and Rockets* (новое название *Technology Week*). По материалам этого же журнала составлены главы о перспективах развития оперативно-тактического, стратегического и космического ракетного оружия США.

При работе с книгой следует учитывать, что все приводимые данные (особенно количественные характеристики) должны рассматриваться критически, так как в ряде случаев они носят рекламный характер. Все параметры, содержащиеся в таблицах части III, вообще являются условными и служат лишь для иллюстрации соответствующих расчетов, что специально оговорено в тех американских изданиях, откуда эти таблицы заимствованы. Условной является и нумерация частей и подразделений, упоминаемых в образцах боевых документов.

Список основных источников, использованных автором, приводится в конце книги. В соответствии с оригиналами в книге сохранены как метрические, так и традиционные английские единицы измерения.

Тематическая структура книги дает возможность изучать материалы в любой последовательности. Поскольку каждая часть, равно как каждая глава, охватывает известный объем лексики определенного характера, читатель может выбрать интересующую его тему и изучить соответствующую часть (или главу) по своему желанию. Материалы, имеющиеся в книге, могут быть использованы как в качестве основных учебных текстов, так и для практики в переводе со словарем, составлении аннотаций, реферировании, для внеаудиторного чтения и других видов работы.

Изучая терминологию по рассматриваемой тематике, следует иметь в виду два обстоятельства. Во-первых, в

ряде случаев английская терминология еще не установилась. Несмотря на наличие определений, содержащихся в большинстве изданных в США толковых словарей, все еще не унифицировано употребление таких общих терминов, как *missile*, *rocket*, *vehicle* и т. д. Даже в специальной литературе термин *missile* может означать как боевые ракеты вообще, так и только управляемые ракеты, причем наряду с термином *missile* используются термины *rocket*, *guided rocket* и даже *guided missile*. Термин *vehicle* используется для обозначения или ракеты, или корпуса ракеты, или космической ракеты-носителя. Во-вторых, объем понятий, выражаемых рядом терминов на английском языке, не всегда совпадает с объемом понятий, выражаемых их русскими эквивалентами. Например, термин *residual radiation* охватывает явления, одна часть которых по-русски обозначается термином «проникающая радиация», другая — «радиоактивное заражение местности». Термин *monitoring* означает как «дозиметрический контроль», так и «радиационную разведку». Отдельные стороны понятия «радиационная разведка» охватываются таким термином, как *survey*. В тех случаях, когда объемы понятий русских и английских терминов не совпадают, переводчику приходится прибегать к описательному переводу, калькированию или просто транслитерации (с соответствующим примечанием).

Объем книги не позволил снабдить ее подробным англо-русским словарем, поэтому читателю при работе с книгой рекомендуется использовать следующие военные словари, изданные Военным издательством Министерства Обороны СССР:

— Англо-русский военный словарь (М. 1960);

— Англо-русский военно-технический словарь (М. 1965);

— Англо-русский ракетно-космический словарь (М. 1966);

— Англо-русский словарь по противовоздушной и противоракетной обороне (М. 1961);

— Англо-русский словарь по авиационным и ракетным базам (М. 1962);

— Англо-русский словарь по космонавтике (М. 1964).

Книга предназначается для средних и высших военных и гражданских учебных заведений, а также для широкого круга читателей, знающих или изучающих английский язык и интересующихся затрагиваемой в книге тематикой.

Просьба направлять все замечания и пожелания по адресу: Москва, К-160, Военное издательство.

INTRODUCTION

The present stage in the development of military art is marked by the marriage of nuclear weapons to rocket delivery systems. The appearance of rocket delivered nuclear weapons entailed the appearance of a set of principles and instructions governing their combat employment; while the effects of nuclear explosion could not but influence the tactics of ground units. Consequently the three parts of this book expound the US Army views and doctrines on:

— missile and rocket delivery systems (Part One);

— nuclear and thermonuclear weapons; the effects of nuclear explosions; protection from these effects (Part Two);

— combat employment of nuclear weapons; its impact on the tactics of ground units (Part Three).

PART I

MISSILES AND ROCKETS

In Part I of this book the reader will find a brief statement of the principles of modern rocketry, the basic performance data on the main rockets and missiles currently employed by the US Armed Forces, and a very general description of a number of the more representative systems.

Section I

GENERAL INFORMATION

PRINCIPLE OF OPERATION

Numerous types of designs of missiles and rockets have been developed for use against various types of targets. Differ as these designs do all of them have in common at least one characteristic: the principle upon which their engines operate is Isaac Newton's third law of motion: "Every action has an equal and opposite reaction."

The "action" in a rocket engine is the pressure exerted by flaming gases when the propellant, either solid or liquid, is ignited in the firing chamber. The "reaction" is the way the chamber that encloses the gases responds to this action.

As shown in Fig. 1, when the ignited gases in the chamber press the enclosing surfaces looking for an escape, there is only one escape — through the open end called the discharge nozzle. Pushing against the closed end, the hot gases build up pressure that thrusts the rocket

forward while the gases are ejected through the discharge nozzle, just as a cannon recoils from its powder charge or as a blown-up balloon reacts when released and the air

Fig. 1. Rocket engine principle.

escapes. The resultant forward thrust is the "reaction" which gives the rocket its power.

SYSTEMS OF CLASSIFICATION OF ROCKETS AND MISSILES

There are in existence a number of classification principles for the rocket engines and the rockets proper (the vehicle). The more general ones will be described below.

The rocket engines are divided into two main classes — the solid propellant engines and the liquid propellant engines. In the solid propellant engine, all the fuel is contained in a high pressure combustion chamber. Once the propellant is ignited, the rate of combustion cannot be controlled nor can it be stopped and refired.

In the liquid propellant rocket engines, the fuel and oxidizer are carried in tanks, and a feed system is used to force the propellant into the combustion chamber. The rate of combustion in this type of engine can be controlled by the feed system.

The rockets proper (the vehicles) are divided into two main classes — the "free" (nonguided) rockets termed "rockets" and the "guided" rockets termed "missiles."

Free rockets do not contain any guidance mechanism. The launcher imparts initial direction to the rocket, which then follows a normal ballistic trajectory to the target. Free rockets are characterized by the great weight of ammunition, relatively light weight of launcher, and decrease in accuracy as compared with artillery cannon as shorter ranges.

As opposed to free rockets, missiles are vehicles which move above the earth's surface and whose trajectory or

flight path can be altered by a mechanism within the vehicle. Radar, television, heat, or a number of other agencies may be adapted to move the steering mechanism of the missile to direct it on a collision course. Or it may be steered to its target by remote control by means of radio signals.

The type of frame construction furnishes another principle for classification of rockets and missiles. In accordance with this principle all rockets and missiles are divided into the winged and the unwinged groups. The aerodynamics of the winged rocket is similar to that of the airplane, i. e., its flight is determined by the lifting force of the wings. The unwinged rockets and missiles are often called ballistic for they usually follow a ballistic trajectory.

According to their combat missions all missiles and rockets of the US Armed Forces are designated as Strategic Missiles, Tactical Missiles, Air/Space Defense Missiles and Antisubmarine Missiles. The strategic missiles are subdivided into intercontinental ballistic missiles (ICBM) and intermediate range ballistic missiles (IRBM), while the tactical missiles include such subcategories as antitank missiles and anti-low-flying aircraft missiles; the air space defense missiles include antiaircraft and antimissiles systems. Missiles designed to penetrate enemy defenses or launched upon approaching targets for diversionary purposes are called "diversionary" missiles. Missiles used to hamper the operation of radar installations are termed "antiradar" missiles.

The relative location of the missile launcher (or the launcher pad) and the target provides the basis for dividing the missiles and rockets into several general categories (or types). In the US Armed Forces there are four of them: surface-to-surface, surface-to-air, air-to-air and air-to-surface.

The surface-to-surface missile is equivalent to long-range artillery that may be fired from land against troop concentrations, important supply depots, communication centers, or industrial areas.

Under the "US Army policy for the integration of rockets and missiles into the Army weapons system," surface-to-surface missiles are defined by three ranges. Short-range — assault or demolition guided missiles to be

used against armor and fortifications; medium-range — missiles to supplement and extend the range or firepower of artillery cannon, to provide close or interdiction fire

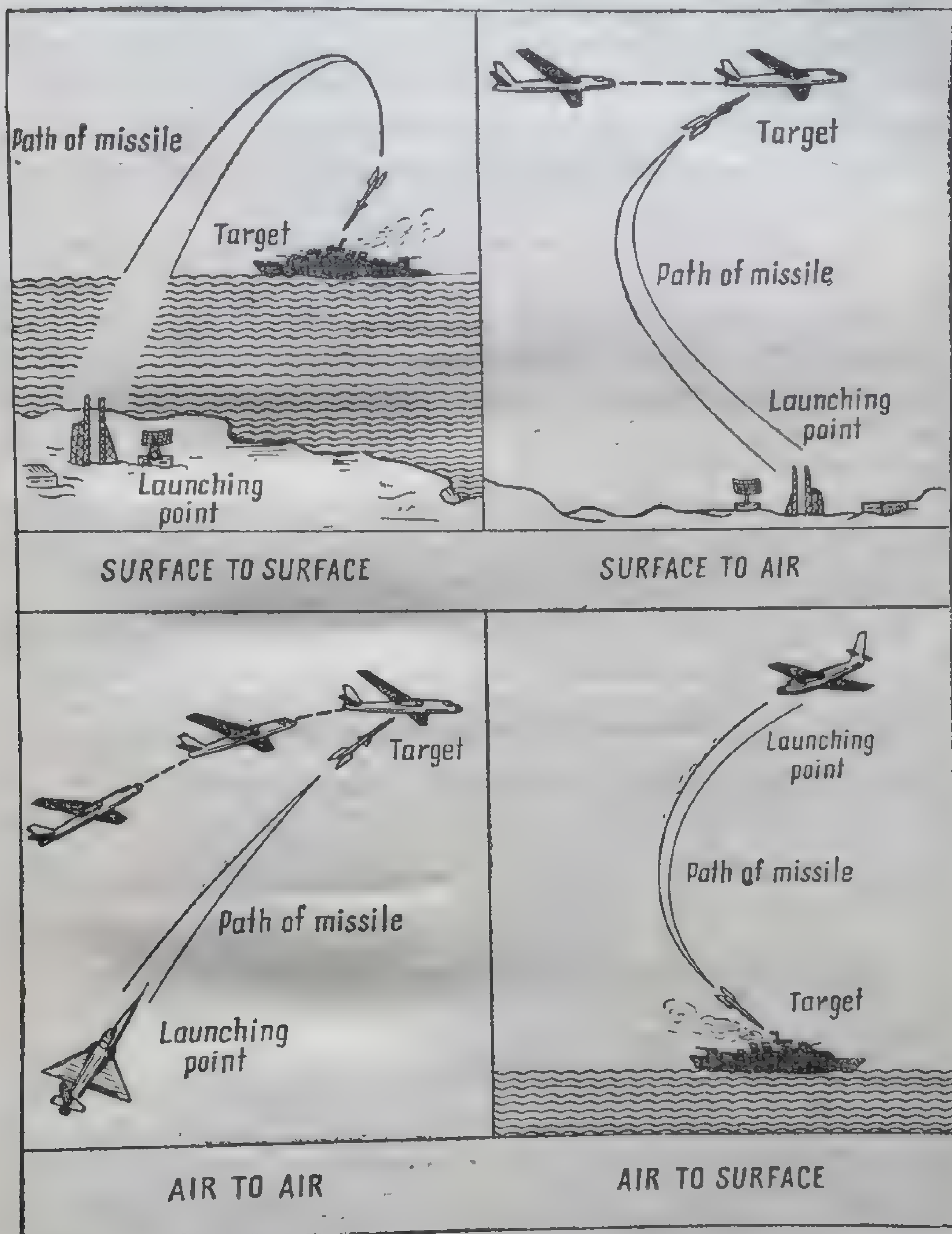

Fig. 2. Four general categories of missiles.

support for ground combat forces, and to compensate for the expanding dimensions of the battle area; long-range — missiles capable of supporting deep penetrations, or airheads, from protected and widely dispersed rear

areas; and of delivering accurate fire on distant targets which are capable of affecting the execution of the Army's combat mission.

The surface-to-air missile is analogous to an antiaircraft shell but is far more lethal and has far greater speed, range, and accuracy. These missiles are effective in destroying high-speed airplanes at all altitudes.

The air-to-air missile is the principal weapon of air-to-air combat. The speed of jet fighters gives them both an offensive and a defensive advantage over the larger and slower strategic bombers that they may attack. However, if bombers are armed with missiles that, when launched, automatically steer themselves toward the attacking fighter and explode at contact or in close vicinity, then they have an effective defense against the faster attacking plane.

The air-to-surface missiles are, in effect, a type of controlled bomb. They are very effective against special kinds of ground targets, bridges, ships, etc.

To characterize a rocket or a missile fully all of the above mentioned principles of classification must be applied. In other words one has to state whether the rocket (missile) is equipped with a solid or a liquid propellant engine, whether the rocket is guided or free, whether the frame is winged or wingless, what the category of the rocket is and what type of combat mission it fulfills.

MAIN COMPONENTS OF THE COMBAT MISSILE

The modern rocket is, in effect, a complex mechanism consisting of thousands of intricate details. The complexity of its design can be easily seen from the fact that V-2, a rocket developed by the Germans towards the end of World War II, consisted of approximately 30,000 parts. The V-2 when judged by the present day standards is a crude and primitive job.

An Atlas (a modern intercontinental ballistic missile) contains over 300,000 precision parts. To produce a modern antimissile missile Hawk the coordinated effort of 40 European and 12 US companies is needed, while the production documentation for this missile includes some

5 million drawings, specifications and technical instructions.

The designs of modern missiles are many and diverse. Any missile however consists of several major parts: a propulsion system, propellants for that system, storage

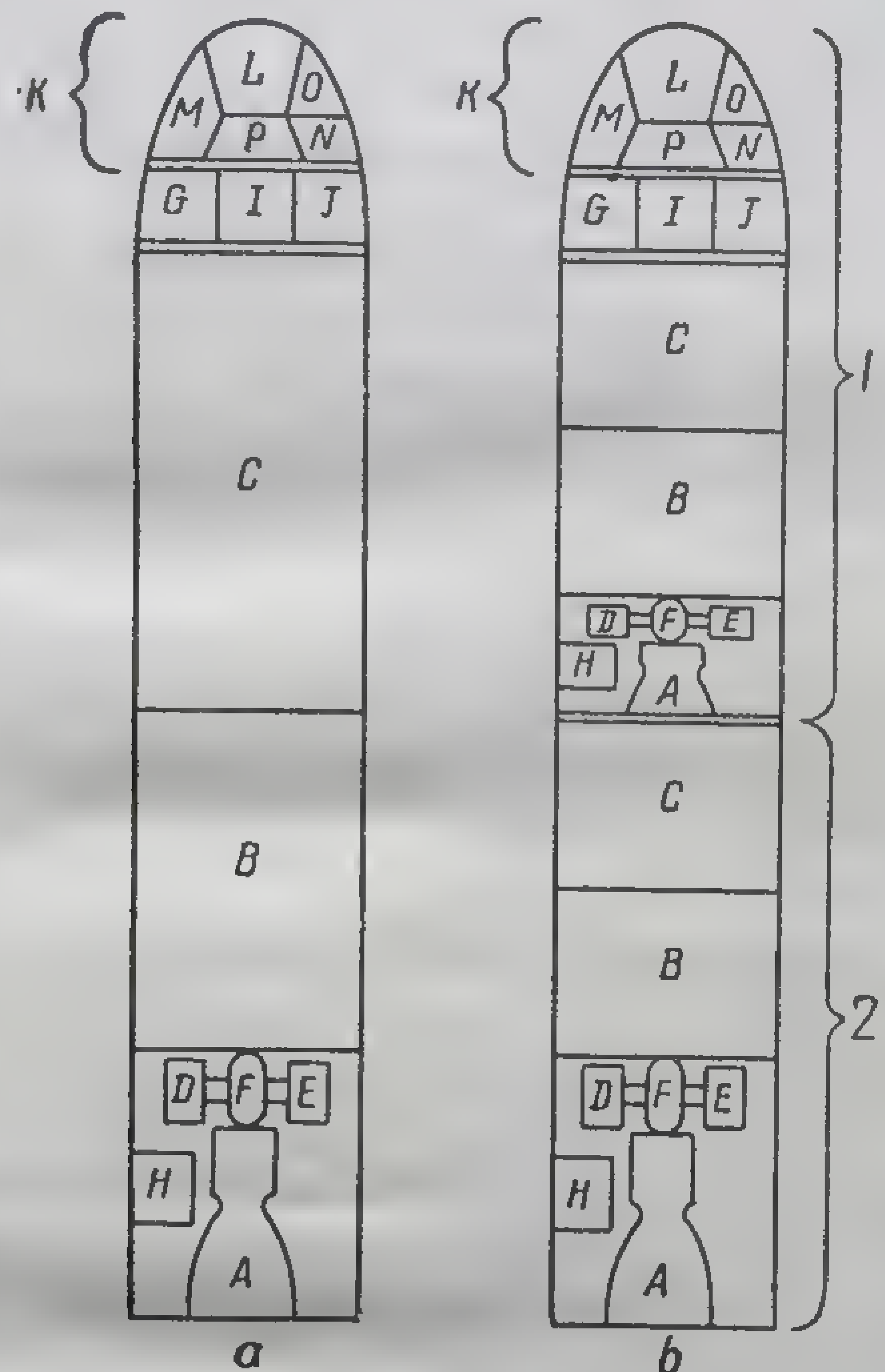

Fig. 3. Overall block diagrams of a typical liquid-propellant ballistic vehicle: *a* — single-stage vehicle; *b* — two-stage vehicle; *1* — the second stage; *2* — the first stage.

tanks for the propellants, a structure which is able to communicate the propulsive thrust to the payload, a guidance system, auxiliary power supplies and a payload (in the case of the combat missile the payload is conventional, nuclear or thermonuclear charge). The propellant storage tanks and the general structure are often known as the airframe. The airframe of a ballistic missile is then defined as the assembled structural and aerodynamic

components which support the different systems and sub-systems integral to the missile.

Overall block diagrams of typical liquid-propellant ballistic vehicles are shown in Fig. 3. Fig. 3a shows a single-stage vehicle and Fig. 3 b shows a two-stage vehicle.

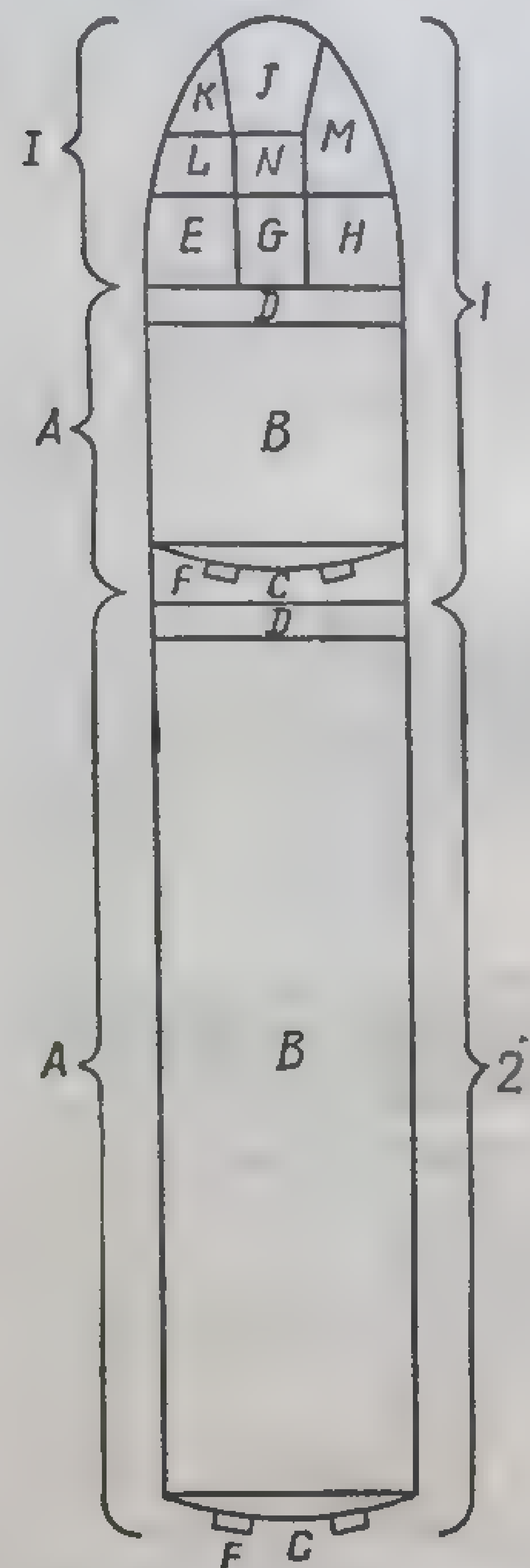

Fig. 4. Overall block diagram of a typical two-stage solid-propellant ballistic missile:

1 — the second stage; 2 — the first stage.

Both the single-stage vehicle and each stage of the two-stage vehicle contain a rocket engine (A), two propellant tanks, one for fuel (B) and the other for oxidizer (C). A turbopump assembly drives the propellants from the tanks to the engines. These assemblies consist of a fuel pump (D) and a propellant pump (E) driven by a turbine (F). The missile is controlled in flight by a control system (G) which operates thrust vector steering devices (H). The control signals are generated as a result of commands from a guidance system (I) which determines whether or not the vehicle is on the correct path to reach its target. An auxiliary power supply (J) supplies electrical and hydraulic power for the various devices and sub-systems within the vehicle as opposed to the main propulsion power supplied by the rocket engines. The re-entry body (K) contains the warhead (L), the fuse (M), the arming mechanism (N), the safety mechanism (O), and the re-entry guidance equipment (P). When a two-stage vehicle is used, some but not all of these sub-systems are duplicated in first and second stages.

An overall block diagram of a typical two-stage solid-propellant ballistic vehicle is shown in Fig. 4. The first and second stages contain a solid-propellant rocket motor (A). This motor consists of a solid-propellant charge (B) and an exhaust nozzle system (C). It has a

thrust termination system (D) to cut off the thrust when the desired velocity has been reached for the payload. In addition, it has a thrust vector control which can direct the thrust for trajectory control.

As with the liquid-propellant missiles, flight control is obtained through the use of a control system (E) which operates the thrust vector steering device (F). The control signals are generated as a result of commands from a guidance system (G) which determines whether or not the vehicle is on the correct path to reach its target. An auxiliary power supply (H) supplies electrical and hydraulic power for sub-systems within the vehicle. The re-entry body (I) contains the warhead (J), the fuse (K), the arming mechanism (L), the safety mechanism (M), and the re-entry guidance equipment (N). In some respects the solid-propellant vehicle is simpler than its liquid-propellant counterpart.

Section II

PROPULSION UNITS AND PROPELLANTS

Propulsion for a ballistic vehicle usually relies upon a rocket system which is defined as propulsion by ejection of matter, all of which is originally carried within the vehicle being propelled. A rocket engine produces an unbalanced force on the vehicle and is thus able to move it. The propulsive action of the rocket engine arises from the reaction to the acceleration, relative to the rocket engine, of a mass of propellant originally carried within the rocket-propelled vehicle. In the rocket engines so far employed in ballistic missiles, acceleration of the propellant mass is brought about by:

(a) releasing heat energy by a chemical reaction of propellants within a combustion chamber, and

(b) the use of an expansion nozzle to produce a supersonic exhaust stream by expanding the evolved gas from combustion-chamber pressure to ambient pressure.

The combustion chamber and expansion nozzle are together known as the thrust chamber.

The thrust chamber has an injector plate. The design of the thrust chamber is governed by the propellants used, the thrust required, the permissible pressure within the

chamber, the altitudes at which the thrust chamber must operate, the combustion temperature, and the method of cooling. After the dimensions of the thrust chamber are determined the throat area, expansion ratio, and flow rate are established. If a long period of combustion is required, regenerative cooling is nearly always used.

Rocket thrust chambers used in ballistic missiles have been fabricated from nickel-alloy tubes through which the coolant flows. The manufacturing process consisted of assembling the tubes in the configuration of the combustion chamber and expansion nozzle, and brazing or welding them together to form the shaped thrust chamber. Originally steel bands were welded around them to give the necessary hoop strength. A considerable weight reduction was later made in thrust chambers by eliminating the steel bands and using untwisted glass filament tape wound around the cylinder.

The thrust vector control is achieved by gimbaling or swivelling the thrust chamber itself as a whole, or by deflecting the jet by jet vanes or paddles, or by swivelling the nozzle.

The control system of the ballistic missile rocket engine has to ensure that the engine can be started and shut down at the correct times. It has also to ensure that the thrust is maintained at a predetermined level and that propellants are fed to the combustion chamber at the required pressures and at the correct mixture rations. The control system must sense any malfunctions and incorrect operations of the start and stop sequences and must shut down the engine if abnormal and dangerous conditions develop. After the shut down of the engine, the control system must arrange for the venting of unused propellants.

Propellants which are used in rocket vehicles can be stored in either solid or liquid form, and the associated engines are known as solid- or liquid-propellant rocket engines respectively.

A rocket engine basically acts as a chamber containing a high-pressure gas which is continuously replenished as some of the gas escapes through an orifice into the region of lower pressure outside the chamber. The simplest rocket engine consists of a chamber — the combustion chamber — in which fuel can be burned in an oxidizer. The

oxidizer can be carried either separately as in liquid propellants or mixed with the fuel as with solid propellants. The fuel and oxidizer are known as propellants. In a liquid-propellant engine they are injected into the combustion chamber. In a solid-propellant motor, the propellant storage tank and the combustion chamber are one and the same. The propellant mixture is triggered electrically, thermally, or chemically, to produce a heat-releasing chemical reaction, and the molecules of the gas produced by the combustion process possess large amounts of energy, moving rapidly in all directions within the chamber. Individually these molecules each have a high kinetic energy but their motions are randomly directed. To achieve a propulsive effect, this random motion has to be directed as uniformly as possible in a direction away from the rocket thrust chamber.

In issuing through the expansion nozzle, the random motion of the gas particles is changed to a more undirectional motion. The gas emerges as a high-velocity stream from the thrust chamber.

Fuels for a rocket engine can consist of many substances ranging from solids such as asphalt, synthetic rubber, beryllium, to the well-known commercial liquid fuels like gasoline, alcohol, jet fuels, and even liquefied gas such as hydrogen. Oxidizers are more limited. Principal substances used are liquid oxygen, nitric acid, and concentrated hydrogen peroxide. Atlas, Titan, Thor, and Jupiter used liquid oxygen as the oxidizer.

When the propellants are solid, they are already in the combustion chamber. Liquid propellants, on the other hand, have to be displaced from storage tanks into the combustion chamber. In small rocket units, this is done by compressed inert gas acting on the propellants in their storage tanks. For large engines of the type used in ballistic missiles, a pump feed is used in which centrifugal pumps are driven by a gas turbine.

Ignition of a ballistic missile rocket engine is the initiation of combustion. During the ignition phase a supporting flame is maintained and a low flow rate of primary propellants is begun. As soon as the propellants are burning properly either an automatic or a manual changeover to maximum performance burning takes place.

TOTAL THRUST. JET VELOCITY. SPECIFIC IMPULSE

All rocket engines produce a total thrust force which is the sum of a momentum thrust resulting from the acceleration of the exhaust gas and a pressure thrust arising from the difference in pressure between the exhaust gas at the nozzle exit and the surrounding air. The total thrust is a maximum for a given rocket engine when the pressure thrust is zero, that is when the exhaust pressure is the same as the ambient pressure. For other than these conditions, the nozzle overexpands or underexpands the gas stream with resulting loss in efficiency. Because a ballistic missile rises through the atmosphere during the period of propulsion, the ambient pressure varies. Ideal expansion conditions cannot be realized, and the design of the rocket engine has to be optimized to allow for the effects of incorrect expansion during part of the propulsion period.

A rocket engine thus consists of a combustion chamber in which the propellants are burned to produce a high-temperature gas, and an exhaust nozzle through which the gas is expanded and accelerated. The convergent-divergent form of the nozzle, needed to give a supersonic exhaust, produces subsonic flow up to the narrowest section, known as the throat, and supersonic flow beyond that section.

The jet velocity of a rocket engine is the velocity at which the gases are discharged from the nozzle. The momentum thrust is proportional to this jet velocity and the mass flowing from the nozzle. The jet velocity is proportional to the temperature of the gas inside the combustion chamber and inversely proportional to the mean molecular weight of the products of combustion. Propellants rich in hydrogen and other light elements are thus advantageous because they lead to a low mean molecular weight of the exhaust gas.

The jet velocity is also dependent upon the ratio of the specific heats of the gas and the thermodynamic efficiency of the process of expansion through the exhaust nozzle. The effective exhaust velocity takes the pressure thrust into account and is calculated from the total thrust and the mass flow.

The mass flow rate from a nozzle is proportional to

the combustion chamber pressure and the nozzle throat area.

The thrust developed by a rocket engine is calculated in terms of the chamber pressure, the nozzle throat area, and a term known as the thrust coefficient. This latter is a function of the nozzle expansion ratio, the specific heat ratio for the exhaust gases, and the external pressure.

The characteristic velocity is proportional to the chamber pressure, the nozzle throat area, and inversely proportional to the mass flow through the nozzle. It is a measure of propellant performance. For example, the characteristic velocity is the combustion chamber pressure required to give unit mass flow for unit nozzle throat area for the propellant used.

The specific impulse of a rocket engine is the thrust per unit weight flow rate.

LIQUID AND SOLID PROPELLANT UNITS. LIQUID, SOLID AND COMPOSITE PROPELLANTS

There are four basic components of a liquid rocket engine propulsion system; the propellant tanks which are usually integral with the structure of the missile contain the propellants before their injection into the combustion chamber. The four engine components are the feed system which is used to move the propellants from their storage tanks into the combustion chamber, the thrust chamber where the propellants are burned and then expelled at high velocity, a control system which starts, stops, and controls the operation of the engine, and auxiliary devices such as means to deflect the jet to change the direction of the thrust vector.

In the turbopump group, there is a turbine, an oxidizer pump, and a fuel pump. Impulse turbines are generally used because, for the desired ranges, they are simpler in design and weigh less per unit horsepower. The working fluid from the gas generator passes through the turbine nozzles where its enthalpy is converted into kinetic energy. The turbine wheel and blades accept the high-velocity gas and the impulse rotates the wheel. The turbine is designed with reference not only to the power level of its operation, but also to the efficiency of the turbine itself. This latter depends upon the velocity of the working fluid, the speed

of the blades, the number of stages, and any gears that may be employed. The exhaust nozzle from the turbine has to be designed so that the power output remains constant with altitude, that is despite changes in ambient pressure as the vehicle rises through the atmosphere. The two pumps are most often of the centrifugal type because this is both efficient and economical in weight and volume. The pumps must be capable of handling large flows at high pressures, without cavitation and without trapping gases in the pump. Usually the design has an impeller that rotates within a casing to accelerate the fluid to a high velocity at the periphery of the impeller. Then the fluid passes into a volute and diffuser which converts the fluid's kinetic energy into pressure energy. The pumps must be designed for a given flow discharge rate and output head. This is governed by the required combustion chamber pressure, the pressure drop through the cooling system and valves and in the injectors. Other important parameters in pump design include the impeller tip speed and the amount of internal and external leakages. The inlet head also has to be established by reference to the suction head required and available, and to the cavitation problems.

The hot working fluid for the turbine of the turbopump comes from a gas generator which can be a "cold" type generator using monopropellants, or a "hot" generator using the combustion of the main propellants of the missile system. A gas-pressurized system uses a separate propellant supply whereas a feed system uses the same propellants as the main rocket engine. A solid-propellant system burns solid propellants to supply the turbine gas. In all these systems, the governing factor is the permissible temperatures of the evolved gases when they enter the turbine. Fuel-rich mixtures are often used to keep the gases at an acceptable temperature.

Fig. 5 shows a cutaway view of a typical liquid-propellant rocket engine for an IRBM. This illustration shows the gas generator and the gas turbine. The gearbox is used to connect the turbine shaft to the propellant pumps. On each pump is a helical impeller which reduces cavitation, and a centrifugal pump which gives the high-pressure output. From the pumps the propellants pass through main control valves to the thrust chamber. They

are injected through injectors into the combustion chamber where they burn. Expansion to supersonic velocity takes place through the convergent-divergent expansion nozzle. The thrust chamber is cooled by the passage of fuel through the many tubes which make up its walls.

With the constant appearance of new chemicals and new low-molecular weight polymers, the versatility in formulating improved propellant fuels will continue to increase.

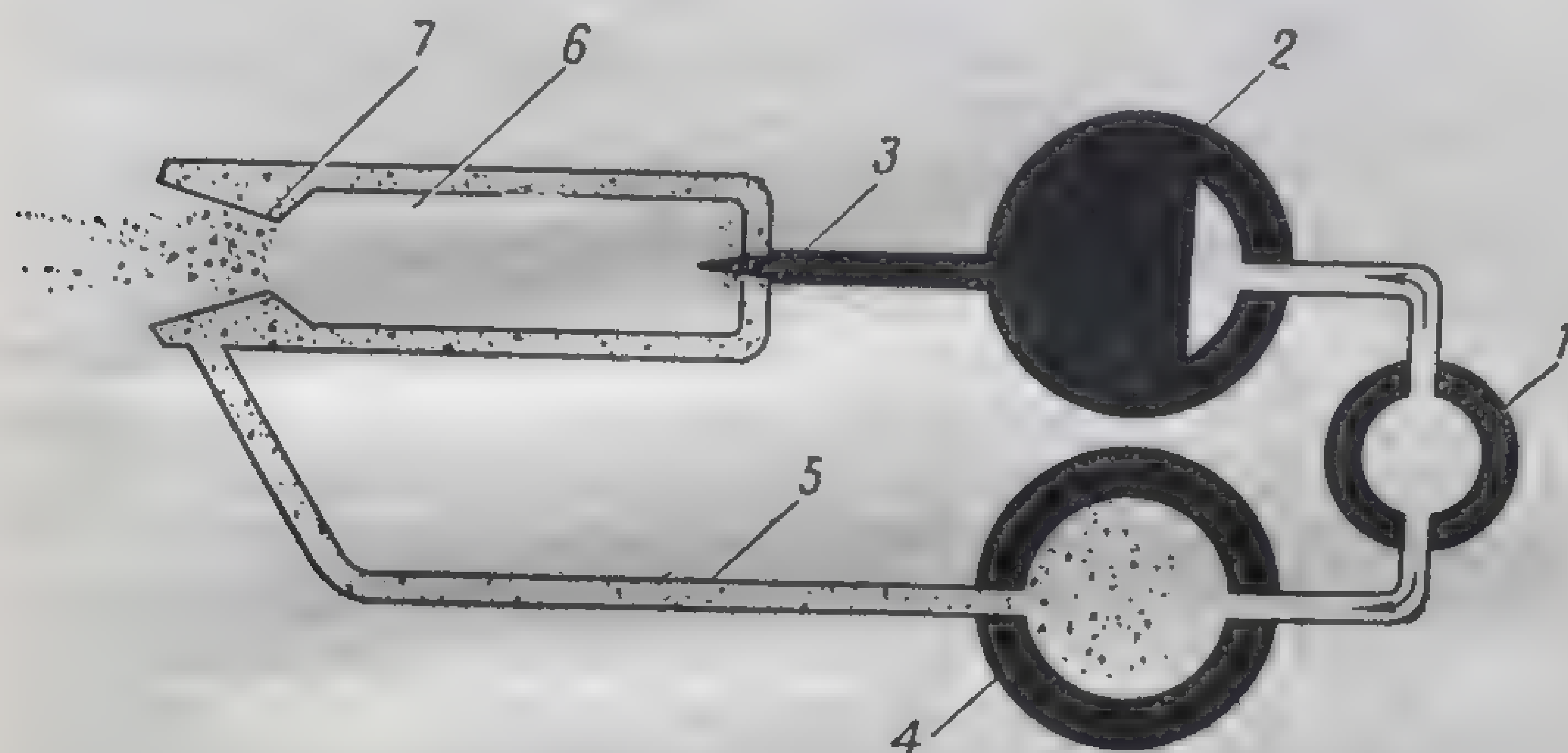

Fig. 5. Cutaway view of a typical liquid-propellant rocket engine: *1* — heavy pressurizing gas sphere; *2* — heavy oxidizer tank; *3* — oxidizer line; *4* — heavy fuel tank; *5* — fuel line; *6* — firing chamber; *7* — discharge nozzle.

Radical improvement is expected in the specific impulse (thrust per unit weight) and in the attainment of the desired burning rate.

The mechanical properties of a propellant are measures of its ability to maintain the integrity of the grain. Therefore, elastic and tensile properties and storage and aging characteristics are vital. Cracking of the propellant grain prior to or during flight of a rocket because of poor mechanical properties may cause a malfunction that would render a rocket useless.

For solid-propellant rocket engines the propellant contains both fuel and oxidizer and is housed in the combustion chamber. Design of the charge shape and the way in which it burns gives control of the thrust forces. The rate of burning is generally defined as the rate at which the surface of the propellant recedes in a direction normal

to the surface which is exposed to the hot gas. This burning rate depends upon the chamber pressure and temperature.

There are two main types of solid-propellant rockets. The restricted burning rocket burns its propellant like a cigarette from one end only and has the other surfaces of the propellant coated with an inhibitor which restricts burning. An unrestricted burning rocket allows the propellant to burn on several surfaces which are shaped to give the required thrust characteristics.

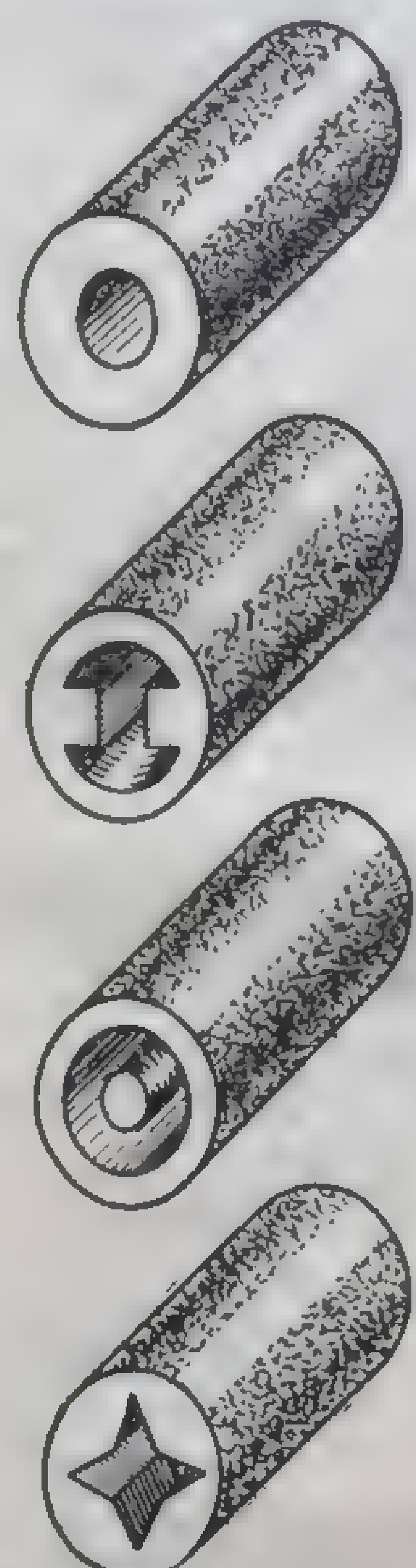

Fig. 6. Typical grain shapes.

Typical grain shapes are shown in Fig. 6. A tubular grain produces a progressive thrust, that is, the thrust progressively increases as the period of burning advances. A double-anchor grain produces a regressive thrust, a rod and tube, and a star grain give neutral thrust, a multifin grain produces a dual thrust, high thrust immediately on ignition followed by a period of low constant thrust.

There are two types of propellants used in solid-propellant rocket engines, one is known as a double-base propellant and the other is a composite propellant. The former consists of nitroglycerine and nitrocellulose whereas the latter uses a granular oxidizer such as ammonium perchlorate mixed with some organic fuel such as synthetic rubber.

The basic conventional propellant combination used in the missile has been liquid oxygen and rocket fuel, which is essentially kerosene. These are relatively cheap propellants costing about two cents per pound for the fuel and less than one cent per pound for the liquid oxygen. Moreover this combination gives a good performance, a specific impulse at altitude of approximately 350 seconds. Storable liquid-propellant combinations give similar performance but have not yet been used extensively. Future impro-

vements may yield an increase in performance to about 450 seconds specific impulse for high-energy propellant combinations, and to about 400 seconds for storable propellants. These latter will probably find increasing use in ballistic missiles because of their great advantages of reducing the problems of logistics and fast propellant loading. Storable propellants are propellants which can be stored within the missile without evaporation or without chemical decomposition of either the propellant or the tank. They thus make the missile ready for immediate firing at all times, and have obvious strategic advantages. Engines designed for conventional liquid oxygen/RP propellants can be operated just as well with the storable propellants. Conversion is straight forward and relatively inexpensive. A common modern storable propellant combination uses nitrogen tetroxide as the oxidizer and hydrazine as the fuel.

Today, composite propellants are composed essentially of three main components: the oxidizer, the metallic fuel, and the fuel binder. Replacement of one or all three of these chemicals by materials having a much higher energy content will lead to propellants of improved performance on the basis of thermodynamic calculations. These calculations indicate that we can, by the use of more energetic oxidizers, light metals, and new fuel binders containing fluorine that have not yet been synthesized, produce propellants with specific impulses 20 to 25 per cent higher than the existing theoretical specific impulse available today. Some of these new chemicals do not yet exist, and we have no assurance of when they will be synthesized, when they will become available, and whether or not they will result in the propellant mechanical properties required to fulfill the existing needs. The use of these ingredients may present some serious problems. These materials must be synthesized and their chemistry understood. If they react with other materials in a propellant, they must be protected either by a metal or a plastic coating, and some of these materials are extremely reactive. Finally, these materials must be used in a propellant formulation and the propellant must be evaluated.

Economic calculations will help to select only those propellants that show both technical improvements and cost reductions for the intended use. These calculations

show that today's propellants are hard to beat, and future solid composite propellants of high energy may have limited applications because of costs. Solid propellants will have new competition either from liquid or hybrid (combination liquid and solid) propellants in various applications. These too may have economic advantages over the future ultrahigh energy solid propellants.

GENERAL TENDENCIES OF DEVELOPMENT IN ROCKET PROPULSION

Advanced flight propulsion technology is in an important transition — from chemical to nuclear energy.

Twenty years from now most space vehicles should be nuclear powered, and nuclear engines will probably be widely used in the atmosphere as well on both aircraft and missiles.

Meanwhile chemical rockets will carry the major operational burden of powering space vehicles and missiles for at least ten years, and they are entering their most promising era. Operationally, the record of chemical-fuel rocket engines gets better every year, engine costs go down in many ways, reliability goes up, and general confidence increases. New designs, the logical extension of existing types, will be lighter, simpler, and more compact.

One important new design area in liquid rockets is new shapes and arrangements of nozzles and combustion chambers:

New materials, higher operating pressures, and new propellants such as liquid hydrogen all are contributing to higher-performance engines. Significant progress has been made in the development of storable, liquid-propellant engines hermetically sealed, instantly ready for use after long periods of coasting in space or storage on the ground.

Liquid rockets, which up to now have been a maze of valves, pumps, sensors, and pipes, are being greatly simplified.

The number and variety of new developments with solid-propellant rockets are even greater than in liquid-engine design. The high reliability already demonstrated by solid rockets is cited as a major reason why they make good boosters for large space payloads. In general, the

takeoff gross weight of any space vehicle would be considerably larger if it were powered by solid-fuel rockets rather than liquid-fuel rockets. Even so, the total cost of booster operations might well be lower if the solid engines were employed.

Very large total weights have been proposed for some solid-fuel booster systems, such as fourteen million pounds and more to put a 250,000-pound payload in orbit.

Under most schemes solid-fuel rockets delivering from 400,000 to one million pounds thrust would be clustered to form the large boosters, and three or four stages would be required to form an adequate vehicle. Each of the engines in the clusters would be more than six feet in diameter and probably fifty feet or so in length. The development of engines in the million and multimillion pound thrust category is of particular significance in view of the research work on missiles with antipodal capabilities and the plans for the military use of space.

The solid rockets used in very large boosters would probably be of relatively conservative design. Beyond these, smaller, higher-performance engines are also under development. They result primarily from improvements in two areas — higher-energy propellants and lighter-combustion cases, nozzles, thrust termination devices, and other items which make up the empty weight of the engine. The spherical engine geometry will provide the lightest engine for any given structural material, and engines of this shape are being tested. Many different kinds of materials are being investigated in an effort to lower the weight of solid rocket cases, including steel wire plastics, die steel, glass filament, and many others.

Major performance improvements are also predicted by engineers working with hybrid rockets, using both liquid and solid propellants. The so-called tri-propellant hybrids are credited by some researchers with about seventy-five per cent of the performance potential of the nuclear rocket, while high-energy liquid-fuel rockets using liquid hydrogen and liquid oxygen have about fifty per cent of its potential. The tri-propellant hybrid engine operation in its simplest form consists of adding hydrogen or some light gas to the exhaust flow of a solid-fuel rocket to lower its molecular weight. The lowering of the molecular weight of the particles in the exhaust flow is

a powerful tool for increasing the specific impulse of the propellant. When the specific impulse increases, the total thrust produced by a given weight propellant will increase and the performance of any given vehicle will improve. It can carry more weight or its final speed can be raised.

Section III

GUIDANCE AND CONTROL

For any guided weapon system the accent must be upon guidance.

Guidance covers two distinct technical problems: first the control of the attitude of the missile, and secondly, the control of the path of the missile. The former ensures correct orientation of the vehicle in space, while the latter has to be solved so that the missile will reach its target. Moreover, attitude control must be effected before path guidance can be attempted.

There are essentially three stages in the guidance of any missile. First is known as the launching phase when control must be employed in order to correct any dispersion following the takeoff, so that the missile can be directed into the correct path for it to enter the next phase of midcourse guidance. Then the guidance system must ensure that the missile's warhead is carried as close as possible to the target with the minimum of time delay. The missile next enters its final stage of terminal guidance in which it has to be brought within lethal distance of the target. Finally the warhead must be exploded; or, if lethal distance is not achieved, a safety device has to operate so that the missile cannot damage friendly personnel or equipment.

Missile guidance systems can be conveniently divided into two classes each of which has its own special peculiarities. The first covers all missiles which move against surface targets — such as the broad categories of surface-to-surface and air-to-surface missiles — where the target is essentially stationary and its position on the surface of the Earth can be observed or calculated. The second class encompasses those missiles which are designed to attack moving targets, mainly surface-to-air missiles and air-to-air missiles. These two broad cate-

gories cover most missiles but there are, of course, borderline cases; for example, air-to-sea and underwater-to-air missiles, which do not fit quite so readily into the general pattern.

The three stages of guidance operate somewhat differently in each class. For weapons which are directed against airborne targets, the first stage following launching often consists of a radar gathering beam having a wide conical form which can bring the missile to the correct flight path as already mentioned. During midcourse guidance the missile can use what is known as beam rider or a system of command guidance, while the final closing to the kill will make use of some kind of homing device.

For surface-to-surface missiles, the launching phase will once more be used to place the missile on its correct initial flight path or trajectory. Midcourse guidance in this class has to extend over a much longer range and will make use of an inertial or navigational system, while target homing might include a device to explode the thermonuclear warhead at the optimum distance from the target area, which may not be at closest approach to the target.

ALL-INERTIAL GUIDANCE SYSTEM. RADIO-INERTIAL SYSTEM

A simple all-inertial system consists of an attitude reference or stable platform, a system of accelerometers, an airborne computer and a timing device or clock. The stable platform gives a fixed frame of reference. The accelerometers detect change of motion along three orthogonal axes, the computer translates these measurements into a measured trajectory and issues control signals to correct any errors which it finds. The clock gives time reference for computing velocity and position.

A simple radio-inertial guidance system consists of an inertial guidance system which supplements radar data, a radar tracker, a computer, and a command link between the ground station and the ballistic vehicle. Position is determined from the radar measurements of azimuth, elevation, and range.

Acceleration is sensed from the inertial system within the missile. The computer uses both the radar positional data and the missile acceleration data to determine velocity. Errors are therefore reduced compared with either a radar system or an inertial system having equipment of similar accuracy. The command link is used to pass data from the ground to the missile.

Although the radio-inertial system has the advantage that it gives greater accuracy in velocity determination it needs a radio command link which is susceptible to enemy countermeasures.

An inertial guidance system uses gyroscopes to establish a set of axes isolated from the motion of the ballistic missile. The gyroscopes produce a stabilized platform to orientate these axes and give a fixed frame of reference against which acceleration along each axis can be measured. Three single-degree of freedom gyroscopes, or two two-degrees of freedom gyroscopes, are used. The force measured by the accelerometers is made up of the force resulting from the acceleration of gravity and that resulting from any acceleration of the missile relative to inertial space. Once the acceleration has been determined the application of the accelerometer outputs to the computer allows an integration to determine velocity and a further integration to obtain position. The computer also takes into account the changing value of gravity as a function of altitude.

In a typical airborne inertial system it is usual to have the sensitive direction of the accelerometers perpendicular to the vertical and thus avoid computing gravity to high orders of accuracies. As the vehicle moves across the surface of the Earth and the direction of the local vertical changes relative to the inertial platform, torquing signals are applied to the gyroscopes to precess the platform and maintain perpendicularity of the system. Such a system is known as a local vertical fixed system.

An alternative system is termed an inertially fixed system. In this system the platform remains fixed with respect to inertial space.

As already mentioned the gyroscopes that are used in inertial guidance systems are of two main types, a two-degrees of freedom gyroscope and a single-degree of freedom gyroscope. The first type uses the characteristic

of the gyroscope that the rotor spin axis remains fixed in inertial space unless disturbed. If the housing of the gyroscope is rotated the spin axis changes relative to the case, and this rotation can be converted to an electrical signal by pick-offs such as potentiometers.

The single-degree of freedom gyroscope is better from the standpoint of drift rate than the two-degrees of freedom gyroscope. This is because it has fewer gimbals and is easier to balance.

The common single-degree of freedom gyroscopes are viscous-damped devices in which the gyroscope rotor is contained within a housing which floats supported in a viscous fluid. Bearing friction is thereby reduced, with consequent reduction in random drift rate. The input axis is perpendicular to the output axis and to the spin axis of the rotor. A microsyn torque generator and a microsyn signal generator are mounted on the output shaft.

Accelerometers have certain basic elements. These are a mass, a force or torque summing suspension member, an indicator of linear or angular displacement, and a restraining device to control the force or the torque. In the accelerometer the acceleration-sensitive mass is constrained to move in a single plane. Transducers, such as signal generators and varying inductances or capacitances, give an output signal suitable for passing to the computer. The control of the force or torque is obtained by use of gyroscope rotors, microsyn torque generators, and other devices.

BEAM RIDER SYSTEM

The beam rider system of control is mainly used for ground-to-air missiles. It depends upon a narrow coded radio beam which is locked on to the target by radar. The missile is gathered by a wide angle beam during the initial phase and brought into the tight control beam. The internal guidance system of the missile then keeps it centered on the tight beam leading to the target. The width of the control beam is important, for if it is too wide the missile will miss the target at long ranges, while a beam which is too tight may lose the missile during the final maneuvers where rapid transverse accelerations are needed. Another problem associated with beam rider is that the

beam can be reflected from various parts of large bombers and give rise to inaccuracies because the beam is not centered exactly on the target.

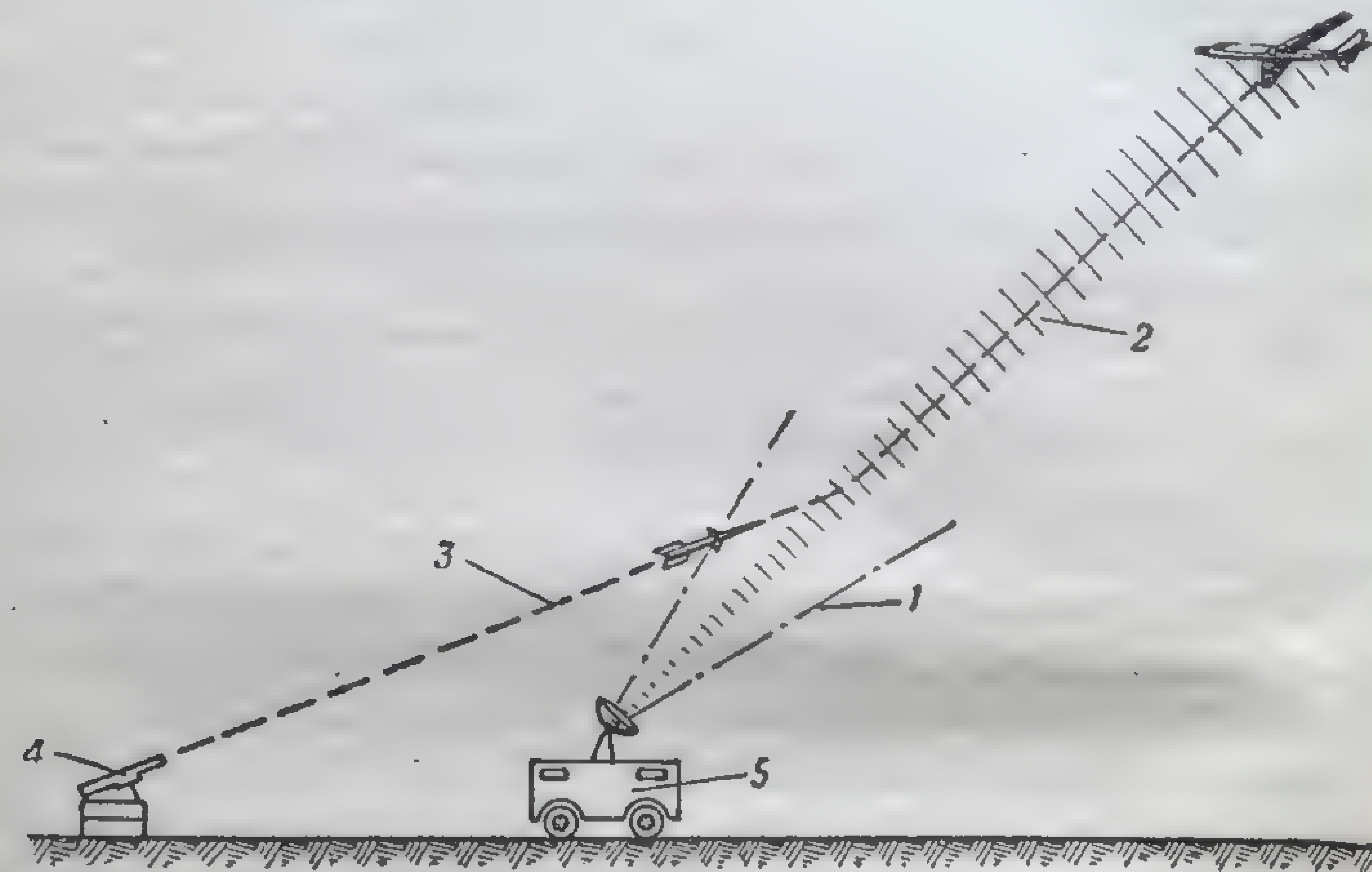

Fig. 7. Radio-beam guidance system with one radar station: *1* — wide beam; *2* — narrow beam; *3* — missile's flight trajectory; *4* — launching pad; *5* — radar guidance section.

HOMING SYSTEM

Most missiles nowadays incorporate some system of homing to close in on their targets without control from the ground station. Homing can be passive where the missile is attracted by a source of energy in the target, for example, heat, electromagnetic waves or noise, radiated from the aircraft's engines or equipment, or even heat radiation arising from the aerodynamic heating of fast-moving bodies. The equipment in the missile then consists of sensitive directional detectors which can operate the servocontrols to put the missile on the correct heading for it to achieve interception.

A semiactive homing system uses radiation from the target which is produced by the defenses. Analogous to the old antiaircraft searchlights a powerful radar transmitter called "lamp-set" is used to illuminate the target. The detectors in the missile then home on the radiation reflected from the target aircraft or missile. Sometimes

the "lamp-set" is carried in a mother aircraft for use with air-to-air missiles.

The most advanced stage is however known as active homing, in which the missile contains the means of emitting its own searching radar impulses.

CONTROL

Surface-to-surface missiles and air-to-surface missiles use a three-stage guidance. The initial stage in the case of ground-launched missiles is used to place them on the correct flight path for winged missiles, or moving at the correct speed on the ballistic trajectory in the case of long-range ballistic vehicles. In air-to-surface missiles it will consist of navigating the aircraft to the correct position for launching the missile. Plotted trajectory systems, which have definite range limitations, rely upon surface radar to plot the course of the missile so that guidance control impulses can be sent to it or the terminal guidance phase can be initiated. A coded radar responder is used in the missile.

The most critical control problem is that associated with the launching of multistage rocket vehicles. Small errors in trajectory and all-burnt velocity of, say, a third stage can place the missile well off its target.

Because long-range missiles are invariably expensive items of equipment, and are necessarily expendable, it is sound economy to include within them even more expensive control equipment so that they may be assured of reaching their target.

A missile has three main degrees of freedom when it is in flight. It may roll, pitch, and yaw, that is rotate about three orthogonal axes which originate at the center of gravity of the missile. The roll axis is along the length of the missile, the yaw axis is in the trajectory plane, and the pitch axis is normal to the trajectory plane. The attitude control system of the missile must keep the vehicle headed in accordance with the programme required to establish entry into the free-flight trajectory. Thus the control system must maintain the vehicle in a vertical plane passing through the launch pad and the target, and must turn the missile about the pitch axis in a pro-

grammed way so that it is heading in the correct direction at the instant of burnout. Position and rate gyroscopes are needed for each axis of the three degrees of freedom.

Attitude control is different from guidance. The latter makes sure that the missile reaches a predetermined place. Attitude control makes sure that the missile has a certain orientation in space at given times.

The three common methods of controlling the attitude of a rocket-propelled vehicle depend upon generating a moment about the center of gravity of the vehicle to cause rotation about that center. Small forces only are required if the moment has a long arm. The three methods are use of aerodynamics forces, deflecting the thrust of the main rocket engine, and use of auxiliary thrust-producing devices.

The two methods suitable for ballistic missiles are auxiliary thrust devices and deflection of the thrust vector produced by the main power plant.

There are various auxiliary thrust devices which can be employed, such as small solid- or liquid-propellant rockets, gas bleed from the main rocket engine, turbine exhaust, gas generators. The thrust vector direction can be changed by jet vanes, jet paddles, jet rings, a gimbaled thrust chamber.

Liquid-propellant ballistic vehicles have used vernier engines, which are small liquid-propellant engines, and deflection of the main thrust vector.

Solid-propellant ballistic vehicles can use jet rings — jetavators — or jet paddles. The advantage of these methods over jet vanes is that drag and disturbance of the jet only occurs when attitude corrections have to be made. In the neutral position the jet deflector is withdrawn. A jet ring is a very efficient device and is gimbalmounted to produce a reliable and simple system which does not make heavy power demands on the auxiliary power system. The attitude control forces are also almost linearly proportional to the ring deflection thereby simplifying the control requirements. With a single nozzle solid-propellant unit additional roll control devices are required. With a multiple nozzle unit of the kind which appears popular for ballistic missile use, roll control can be obtained by jet deflection of the main engine thus obviating any need for attitude controlling verniers.

Those liquid-propellant rocket thrust chambers which use directional control of the thrust vector are pivoted at the injector head, the motion being controlled by actuators which have to be attached to suitably strengthened parts towards the rear of the thrust chamber assembly. A major difficulty with the pivoted engine is that of supplying propellants at high pressure through the necessary flexible couplings. Bellows type couplings have been used for this purpose.

Section IV

RE-ENTRY BODY

The payload of any ballistic missile is included in the re-entry body or re-entry vehicle which houses, protects,

Fig. 8. Mating of the warhead of the Sergeant military missile.

and transports the explosive warhead during the flight through space and high-speed re-entry into the atmosphere. The re-entry body, which was at one time referred

to as the nose cone, is a major sub-system of the ballistic missile.

Usually the re-entry body is separated from the air-frame after the propulsion period or propelled flight of the ballistic missile. The re-entry body then follows a ballistic trajectory through space towards the target. On the downward leg of the ballistic trajectory the speed of the re-entry vehicle increases because of the acceleration of gravity, and the vehicle accordingly descends into the atmosphere at a high enough velocity for aerodynamic heating to produce extremely high temperatures.

MAIN COMPONENTS

Essentially a re-entry body consists of several parts or sub-assemblies, including the payload, a structure, and a heat shield.

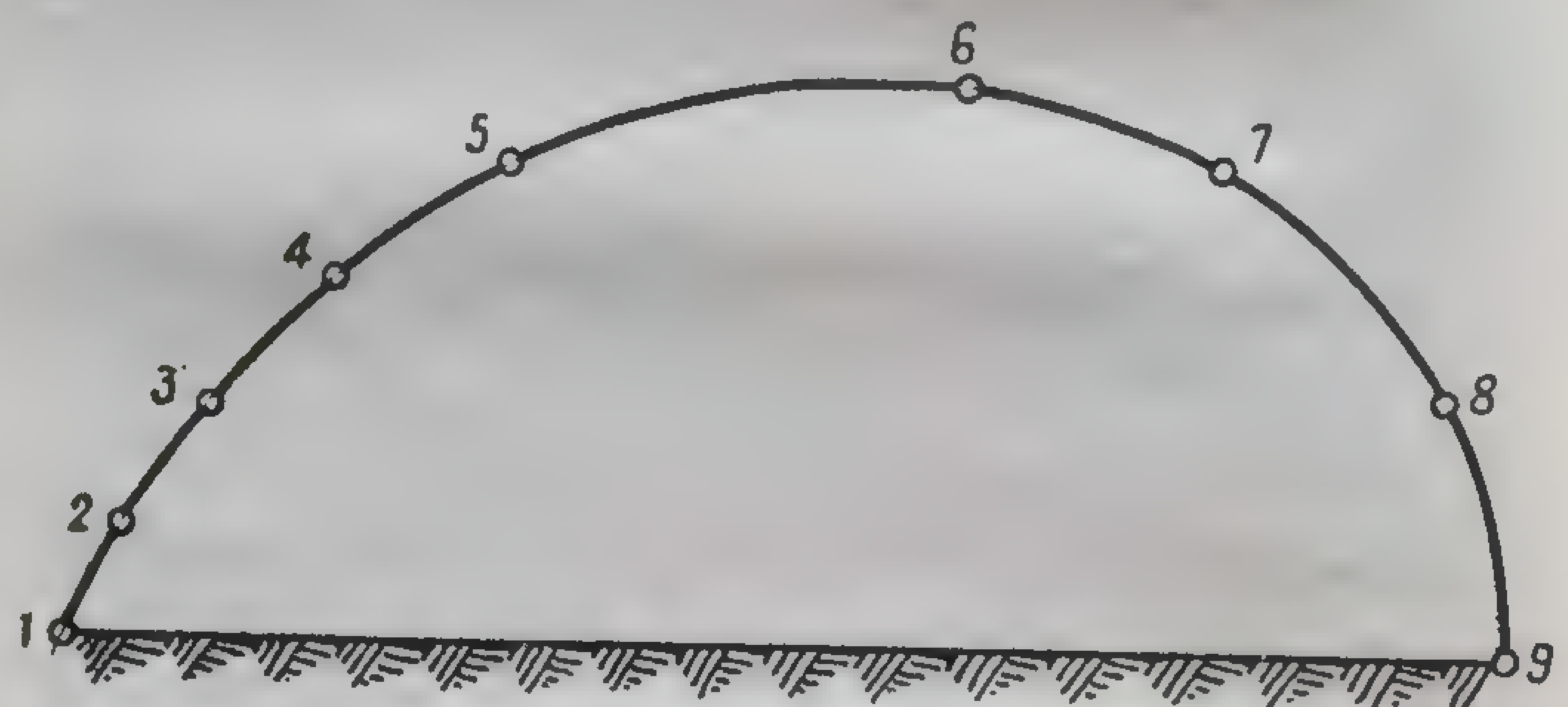

Fig. 9. Working sequence of warhead assemblies:
1 — firing; *2* — timer; *3* — propellant feed system; *4* — speed sensing safety device; *5* — pressure system safety arming; *6* — warhead arming; *7* — fuse arming radar; *8* — air burst radar or timer; *9* — ground burst impact crystal.

The weight of the warhead will depend on its design. A modern ICBM warhead will weigh about 600 pounds. In view of the high cost of missiles compared to warheads it would appear that a prime military requirement would be the development and proving-out of smaller ballistic missiles which could be fitted with a warhead weighing only 200 pounds. The obvious military advantage would be the great reduction in missile size and greater ease in basing the missile system.

From the standpoint of the mission the most important item is the payload and its explosive warhead. Support for the warhead consists of the safing, arming, and fusing devices, an attitude control system which corrects the terminal trajectory so that the re-entry body has the correct orientation as it plunges into the atmosphere, and a power supply for these units. This latter provides electrical power for the support equipment.

The safing, fusing, and arming system keeps the warhead safe until the re-entry body has reached a certain part of its trajectory, and then arms the warhead so that

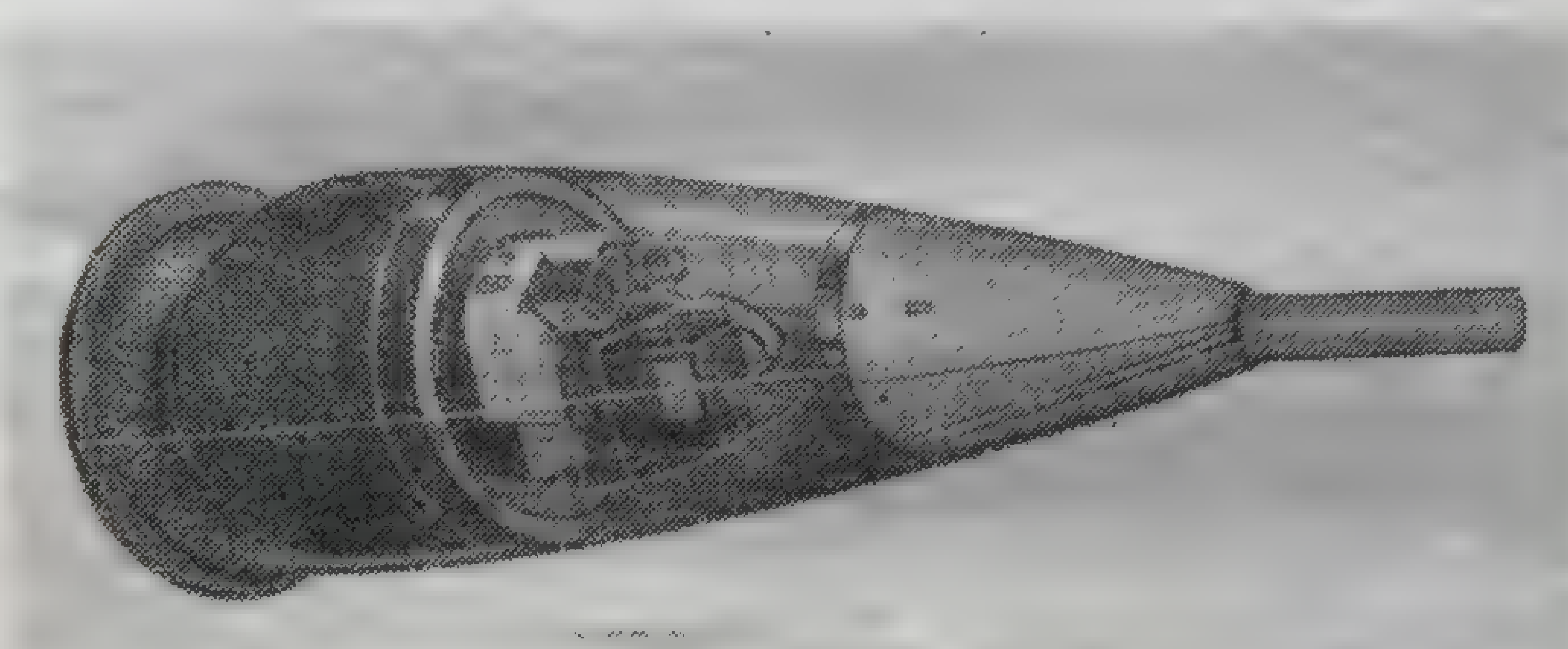

Fig. 10. General view of a warhead.

it will explode at some desired point on the re-entry path as preset to allow for the yield of the warhead and the type of attack planned. The warhead itself may be either a thermonuclear or conventional explosive device depending upon the strategic or tactical use of the missile and upon its mission.

The payload may also include a separating device, vernier propulsion system for adjusting velocity after separation, and countermeasures to confuse enemy defenses. Advanced missiles may also include small rocket engines to give manoeuvrability to home on targets or to change the trajectory and confuse defenses.

The second major part of the re-entry body is the structure. This supports the various assemblies and components which make up the payload and it holds them in their correct relative positions during the acceleration of powered flight and the deceleration of re-entry. The structure is essentially a supporting device which with-

stands aerodynamic and other loads and vibration effects during the mission. It also acts as a support for the heat-protecting shield. As in the rest of the ballistic missile weight is at a premium. Any unnecessary weight in the structure of the re-entry body carries a penalty in launching weight of the vehicle.

HEAT PROTECTION

The skin or shield which protects the structure and the enclosed payload during re-entry into the atmosphere is basically a heat protection device. It is designed to prevent the passage into the interior of the re-entry body of heat arising from the transfer of kinetic energy from the body to the surrounding air with consequent raising of the air's temperature. The protective shield can be designed in several ways. It may, for example, act as a barrier to prevent the passage of heat, or it may be designed to absorb a certain amount of heat without unacceptable rise in temperature.

Barriers can be established by using *transpiration cooling*, *insulation*, or *ablation* systems. In *transpiration cooling* a material is forced through porous walls from the interior to the surface of the heat shield. The heat of evaporation reduces the heat transfer into the re-entry body from the surrounding air. Insulation consists of a ceramic skin which resists the transfer of heat because of its low heat transfer rate. Ablation utilizes the melting, vaporizing, or decomposition of an insulating material to absorb heat and also to change the boundary layer so that it retards the input of heat to the re-entry body.

Heat absorbers use a heat sink fabricated from material of high heat capacity. This shield is able to absorb large quantities of heat without producing an unacceptable rise in temperature of the payload.

Re-entry heating is a problem because of the tremendous kinetic energy possessed by a re-entry body when it falls along its ballistic trajectory back into the atmosphere. The body moves so quickly that the air molecules are unable to have warning of its coming and cannot move out of its way. The air becomes compressed and heated and slows down the re-entering body.

During re-entry at speeds exceeding 10,000 miles per hour the re-entry body approaches the conditions of a man-made meteor. Half of the kinetic energy of the warhead, if changed into heat and absorbed by the re-entry body, would be enough to vaporize the body whatever its material of construction. An idea of the immense amounts of energy involved is gained from the fact that a typical ICBM nose cone possesses as much kinetic energy as a freight train 40 miles long travelling at 60 miles per hour.

The other method of protecting the re-entry body, and one which has become of increasing importance, is that of *ablation* or mass transfer. Heat energy is absorbed by the surface of the shield loosing material into the gas streaming past the re-entry body. The surface material melts, vaporizes, or sublimes. Not only does the change of state absorb incoming heat but also the material removed from the shield enters the boundary layer and by changing the characteristics of the layer reduces the heat transfer through it. Ablative heat shields thus protect the re-entry body in several ways. The heat transfer is blocked because of a mass transfer which thickens the boundary layer. The heat input is reduced because some of the incoming heat energy is used to produce a change in state of the material of the heat shield. In advanced systems still more heat is absorbed by using materials that also undergo endothermic changes in composition.

A cooled type of re-entry vehicle might employ a coolant exuded from the forward part of the body and allowed to flow back from the nose so as to be swept over the body by the airstream. The evaporation of this coolant would absorb heat. This type of cooling can also be obtained when the ablative material at the nose is caused to change into the liquid state and flow back over the rest of the body as a viscous fluid which absorbs more heat as it evaporates or decomposes. Glass has a sufficiently high viscosity for this purpose, but needs additives to improve its radiation properties.

Although actual materials that are used in operational re-entry bodies are highly classified some details have been released that materials can range from pure plastics through plastics reinforced with fibres, to silica, oxides, carbon, and graphite. Plastics have shown satisfactory ablation characteristics. Several special plastics have been

developed which give a rapid mass transfer into the boundary layer together with endothermic reactions or decompositions; for example, heat absorbing depolymerization of Teflon and pyrolysis of phenolic nylon. Teflon is also a good insulator and thus acts as a heat barrier, although it ablates fairly rapidly.

A successful ablation technique depends upon the selection of materials that will decompose under the severe heating conditions of re-entry. This is entirely different from the heat sink type of construction. In an ICBM the transfer rate can be lowered by as much as 50 per cent by the selection of materials which decompose and enter the boundary layer in mass transfer cooling. The efficiency of the process of mass transfer cooling is increased by choosing substances which release gases of low molecular weight into the boundary layer.

NUCLEAR WARHEAD YIELDS AND TNT EQUIVALENTS

Modern missiles are as a rule equipped with warheads, containing nuclear charges which are discussed and described in detail in Part II of this book. The destructive power of the nuclear charge is determined by its effective energy release. Effective energy released in a nuclear explosion, i. e. the yield or the energy yield, is usually expressed in terms of its TNT equivalent. The TNT equivalent of a nuclear explosion is the tonnage of TNT required to produce the same energy release in an explosion. The basis of the TNT equivalence is that the explosion of 1 ton of TNT releases 10^9 calories of energy. The TNT equivalent is usually stated in kilotons or megatons. Kiloton energy is the energy of a nuclear explosion which is equivalent to that produced by the explosion of 1 kiloton (1,000 tons) of TNT. Megaton energy is the energy of a nuclear explosion which is equivalent to 1,000,000 tons (or 1,000 kilotons) of TNT.

The actual weapon yield of the missiles and rockets employed by the US Army vary quite considerably and are determined by the combat mission of the weapon and the principles of its tactical employment. The yields of the tactical weapons, for example, must be such as to avoid the overkill which would endanger the safety of friendly troops (see Part III).

Below is a table stating the announced nuclear weapon yields of a number of systems with the TNT equivalents ranging from several hundred to several million tons:

Type of Missile	Nuclear Warhead Yields
Titan	4 MT
Hound Dog	4 MT
Atlas	3 MT
Minuteman	2 MT
Polaris	.5—1 MT
Pershing	20 KT
Falcon	2 KT
Davy Crockett	.2—.3 KT

According to their nuclear yields the tactical nuclear weapons used by the US Army are broken down into a number of categories each supplied with a code name:

Code name	Nuclear yields
A — Alfa	2 KT
B — Bravo	15 KT
C — Charlie	20 KT
D — Delta	75 KT
E — Echo	100 KT
F — Foxtrot	200 KT
G — Golf	500 KT

Section V

TRAJECTORIES

From the military point of view the ballistic missile has the sole objective of carrying a payload from one point to another on the surface of the Earth, this payload being the warhead of some kind. To fulfil this purpose the ballistic missile must follow a predetermined path or trajectory.

THREE SECTIONS OF A TYPICAL TRAJECTORY

A typical trajectory of a long-range ballistic missile is divided into three distinct sections of which each has its own characteristics. The first section is known as the propelled flight. During the period of propelled flight the payload forms a part of the complete ballistic vehicle. This vehicle is accelerated upwards from the launch pad, launch being defined as the initial motion in transition

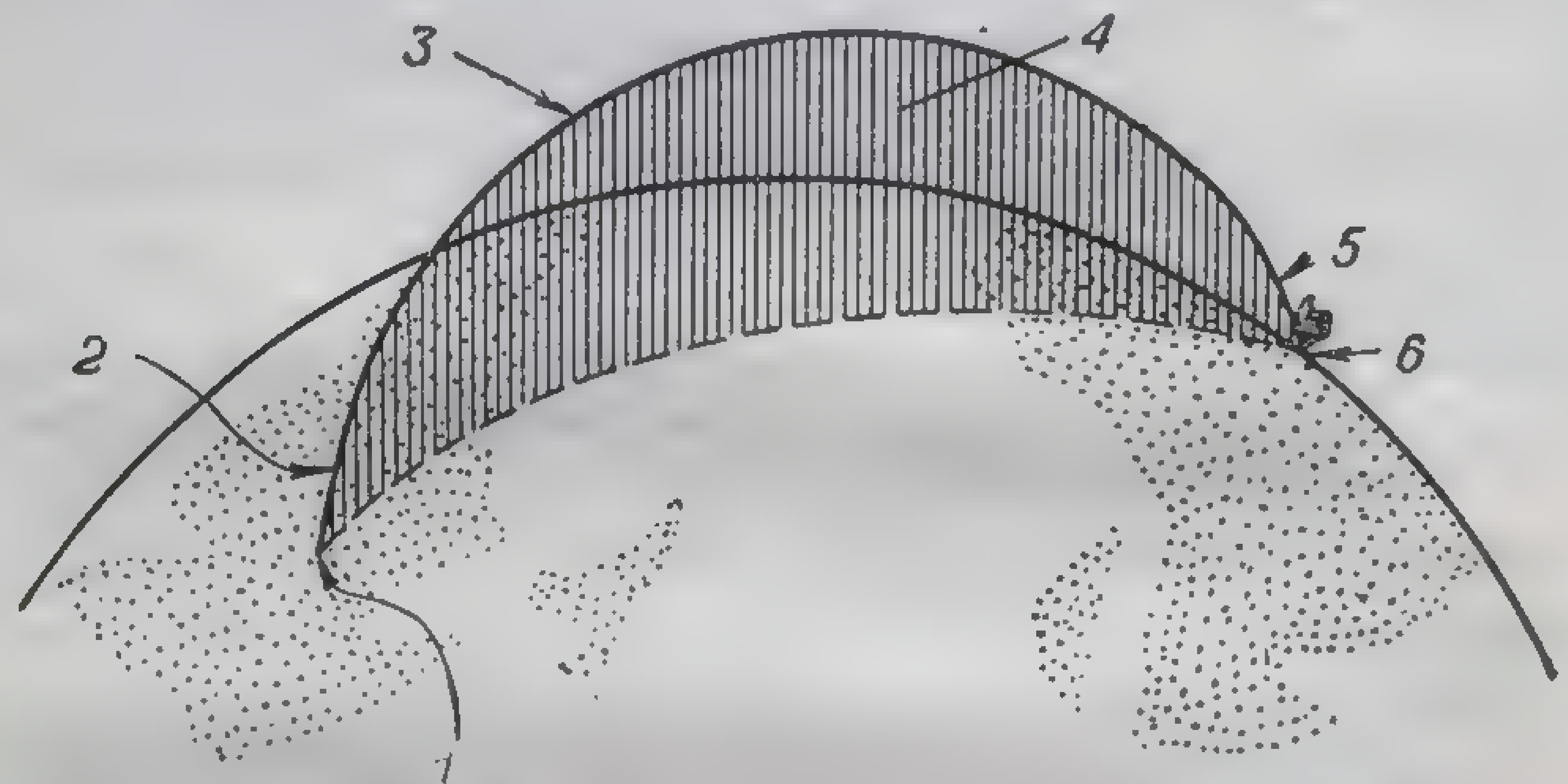

Fig. 11. Typical trajectory of a long-range ballistic missile:
1 — launch pad; *2* — powered flight; *3* — ballistic flight; *4* — trajectory plane; *5* — re-entry; *6* — target.

from static repose to dynamic flight, that is, the moment when the missile is no longer supported by its launcher. Launch is synonymous with takeoff or liftoff.

From a vertical launching of the missile the propelled flight is programmed so that the path of the vehicle gradually pitches towards the target until the motion is at some definite angle to the local horizontal. This programmed turn is preparatory to establishing the flight conditions for injection of the payload into the free-flight path which forms the second section of the typical trajectory. The overall missile design should arrange that all the propellants are consumed by the time the vehicle reaches a suitable velocity for injection. Burnout is the point in time or in the trajectory of the missile when the propellant is exhausted or its flow is cut off to end combustion in the rocket engine. Burnout velocity is the velocity of the vehicle at this time. It is close in value to the

required injection velocity. Burnout angle is the angle that the velocity vector makes with the local horizontal at the burnout point. It is sometimes known as the burnout elevation.

The injection point is above the atmosphere so that the vehicle can follow the free-flight path through space. During this second part of the flight the payload can, if required, be separated from the empty tanks and the useless engine of the large rocket vehicle that has been used to boost the payload to the required velocity. The payload then follows the free-flight trajectory, gradually rising through the gravitational field until it reaches the apex of its flight, a point which is known as the apogee.

Then the payload starts to descent towards the Earth along the downward leg of the trajectory. At some point it re-enters the atmosphere and is then in the third section of a typical trajectory. During this re-entry phase the payload is subjected to deceleration forces and aerodynamic heating and buffeting. The path curves rapidly at the end of the flight and the payload may descend almost vertically on to its target.

CALCULATION OF BALLISTIC TRAJECTORY

The path followed by the ballistic vehicle can be approximated by considering two bodies only, the Earth and the payload, the latter being negligible in mass compared with the former. The Earth can be assumed as being fixed in space, and the motion of the payload can then be described in terms of a system of coordinates centred at the centre of the Earth. The entire trajectory from launch to impact takes place in a plane which is defined by the velocity vector and the point of origin. In the idealized two-body problem there are no forces to cause the payload to move out of this plane. In actual fact there are wind shears which can move the missile from this plane during the powered trajectory and the re-entry trajectory.

A mathematical treatment of the two-body problem shows that if the total specific mechanical energy of the payload, namely the algebraic sum of the potential energy

and the kinetic energy, is less than zero, that is, if it is negative, the trajectory is a part of an ellipse. If the total energy is zero the trajectory is a parabola, while if the total energy is positive the trajectory is a hyperbola. The total specific mechanical energy assumes potential energy as negative and kinetic energy as positive in sign. The specific potential energy is zero when the distance is infinite, and it is a maximum negative value (infinite) when the two bodies are in contact.

The paths of ballistic missiles are always parts of ellipses, that is, the kinetic energy is always less than the potential energy at all points in the path.

The free-flight trajectory of a ballistic missile, disregarding the oblateness and the rotation of the Earth, can be regarded as the path traced out by a body moving under the influence of the inverse square force of gravity directed towards the centre of the Earth. It lies in a plane which contains both the burnout point and the centre of the Earth, and if the burnout velocity vector is directed correctly in azimuth the target will also be in this same plane.

When the launch point and the target of the ballistic missile have been established the trajectory curve still cannot be determined until some other parameters are also defined. Assuming that the range and the length of the radius vector are known at the burnout point, it is also necessary to know the magnitude and the direction of the payload's velocity at this point that are required to carry the payload along the elliptical path to the target. There are, in fact, an infinite number of elliptical trajectories which could be used to carry the payload from the burnout point to the re-entry point, but until other limitations are established it is impossible to define the best trajectory. For a ballistic missile to reach a given range from the burnout point there are infinite combinations of burnout angle and burnout velocity, but there is an optimum burnout angle for any range which produces the least burnout speed requirement for that range. A limitation might accordingly be placed on velocity or on angle. The other unknown could then be determined. Because the magnitude of the burnout velocity is a function of the amount of propellant carried relative to the payload, propellant economy and hence economy in initial launch

weight will be obtained by minimizing the magnitude of the burnout velocity vector. One way of attacking the problem is to determine what is the maximum range that can be obtained for a given burnout velocity. There is a maximum range trajectory for any given burnout velocity, and this is called the minimum energy trajectory. For a given burnout velocity there is only one direction of the burnout velocity vector which can produce the minimum energy trajectory. However, it may not be desirable to choose the minimum energy trajectory from the standpoint of guidance requirements.

Consequently, if the missile design is such that the range required is less than the maximum range for a given burnout velocity, there are two solutions for the burnout angle. They yield a high trajectory — a lofted trajectory — and a low trajectory.

The target, the launch point (or really the burnout point or injection point into the ballistic trajectory) and the centre of the Earth define the plane of the trajectory. The velocity vector at burnout must lie in this plane. In practice there can be errors, for example, the position of the burnout point could be incorrect, the magnitude of the velocity vector and the direction of this vector could also be in error.

To achieve the primary function of a ballistic missile the weapon must be designed to hit a specific target. Many varied influences have to be accurately considered together with their interactions. General equations to solve the overall problem are cumbersome and are difficult to manipulate even with the aid of large digital computers. Instead of attempting a general solution to the problem calculations are made for specific instances with selection of the trajectory which the missile is most likely to follow. The miss coefficient or influence coefficients give an indication of the performance tolerances that can be allowed in the design of the vehicle. Because the miss coefficient assumes that one error only occurs at a time, the multiple effects of several errors introduce complications which need very involved computation to arrive at a correct solution.

The designer of the ballistic missile has also to allow for the permissible dispersion of the impact points. This depends in turn on the yield from the warhead, the size

of the target itself, the nature of the target, the type of attack that is planned, and the accuracy with which the position of the target is known. Many distances over intercontinental ranges are known only to within a few miles.

The permissible dispersion of a ballistic missile is generally defined in terms of the circular error probable (CEP) which is the radius within which one-half of the successful missiles must impact. Only missiles that actually lift off and are injected into the ballistic trajectory are taken into consideration in calculating the CEP.

During the final part of the trajectory, where the re-entry body has re-entered the atmosphere and is being decelerated rapidly as it falls towards the target, the trajectory changes from the elliptical shape of the free-space trajectory and steepens as the vehicle falls towards the surface of the Earth. This increased curvature or steepening of the trajectory is caused by deceleration of the missile by aerodynamic drag.

At the point of re-entry into the atmosphere the vehicle is travelling extremely fast, and re-entry has to be programmed so that neither the deceleration forces nor the aerodynamic heating become unacceptable for the safety of the re-entry body. The controlled re-entry is achieved by suitable design of the profile of the nose of the re-entry vehicle. Very blunt bodies have rapid deceleration so that they fall upon the target relatively slowly. Bodies with more pointed noses have lower deceleration and approach the target more rapidly. There are, however, disadvantages to either approach. A blunt-nosed body, while it can avoid serious aerodynamic heating, approaches the target so slowly that it could be intercepted by an anti-ICBM missile. The fast re-entry body on the other hand reaches high temperatures. Early American re-entry bodies used the blunt-nosed configuration. Later the heating problems were overcome and the more pointed nose was used.

During re-entry there can be a target error caused by unpredictable winds and meteorological conditions in the vicinity of the target. An ablative type of re-entry body using a more pointed nose can approach the target more quickly with deceleration lower in the atmosphere so that it is less effected by side gusts.

Section VI

DEVELOPMENT OF MILITARY ROCKETS

(General Outlines)

Below is a brief summary of the highlights in the development of military rockets.

Listed in the chronological order of their introduction the main types of nuclear delivery weapons are:

— large ballistic rockets launched from fixed emplacements;

— strategic cruise-type missiles (pilotless aircraft);

— ballistic rockets launched from ships, particularly from submerged submarines;

— aircraft used as airborne launching platforms for cruise-type missiles;

— ballistic rockets mounted on mobile launchers;

— ballistic rockets launched from aircraft;

— ballistic re-entry vehicles ejected from a satellite or spacecraft;

— ballistic re-entry vehicles launched from controllable hypersonic vehicles above or within the atmosphere.

What are the advantages, disadvantages and prospects of these eight general types of delivery systems?

Ballistic Rockets Launched from Fixed Emplacements. The large ICBM may have the range of some 9,000 miles and a warhead of about 4 MT. Their effectiveness however depends to a very large extend on the resistant capabilities of launching installations. These installations being fixed present attractive targets for nuclear attacks; to withstand them the so-called "hardened" complexes are constructed. The complexes serving the liquid fueled radio guided systems were in effect extremely expensive underground sites housing several hundred people and most intricate machinery. The very complexity of these installations limited their survivability in case of a large scale enemy attack with nuclear weapons of the multi-megaton range. Introduction of all-inertial guided systems operating on modern solid fuels improves the overall picture. The complexes have become infinitely simpler; human beings are eliminated from the entire complex; no propellant tanks or loading systems are needed; the only supporting service

is checkout console. The human launch crews operate from a headquarters directing as many as 50 complexes. The communication system between the headquarters and the launching sites (complexes) is based on the earth-current radio network employing burried aerials and dispensing with cables. The earth current system is not only cheap but is very difficult to jam, destroy or sabotage.

Strategic Cruise-Type Missiles. The types employed now are of little practical significance. Not only can they be shot down by a ground launched missile but even intercepted by fighters. The advent of nuclear powered vehicles of high endurance, flying at supersonic speed very close to the earth's surface will spell a drastic change. Most difficult to intercept these vehicles could range far and wide in a completely unpredictable manner carrying any of a variety of weapons.

Submarine-Launched Missiles. The vulnerability of a modern ballistic missile submarine is quite low. They can lie at rest for months without making a sound. Their chief drawback is the weight and cost of the missile. Just the first stage of a submarine launched intercontinental ballistic missile is estimated to weigh around hundreds of tons and cost many millions of dollars.

Air-Launched Missiles. Although missiles of this type are just supersonic their operational versatility, ability to conduct violent programed maneuvers, the large payload make them quite attractive against even well-defended targets. It is felt however that missiles of this character while conferring a valuable increase in penetrative ability upon existing bombers will not be able to live in the defensive environments of the second half of this decade.

Missiles on Mobile Launchers. Most tactical weapons have for many years fallen into this category but from the strategic viewpoint the first plans to design such weapon system are just being developed.

Air-Launched Ballistic Missile (ALBM). The ALBM provides mobility and dispersal, and through these overall effectiveness far greater than can be achieved by a fixed-base missile. On the other hand the ALBM is quite vulnerable to countermeasures. The ALBM reentry vehicle can be detected, tracked and destroyed; the

bomber carrying it could be shot down or even destroyed at home base.

S a t e l l i t e s. A satellite can be turned into a mobile base from which a re-entry vehicle can be launched. A satellite could be provided with a propulsion system capable of being started and stopped in space in order to modify the orbit considerably. At the same time it is considered that a satellite could be intercepted by the existing anti-missile means.

C o n t r o l l a b l e S p a c e c r a f t. This class of aerodynes may function as hypersonic gliders, skip vehicles, alternately entering and departing from the upper reaches of the atmosphere, or pure re-entry vehicles which can be streered through the atmosphere. Naturally all these offer entirely new military possibilities. From the viewpoint of warhead delivery they offer the ultimate in penetrative ability and accuracy. The trajectory of a hypersonic aerodynamic device, unlike the re-entry vehicle of an ICBM, need not be ballistic. It could perform considerable changes in direction, and, when the formidable problems of heating and acceleration have been overcome, might be able to maneuver like an ordinary airplane.

Section VII

BASIC PERFORMANCE DATA ON U. S. ARMED FORCES ROCKETS AND MISSILES

The missiles and rockets ennumerated here are broken down in accordance with their combat missions — Strategic Missiles, Tactical Missiles, Air/Space Defense Missiles.

The basic performance data on each missile includes the data on its range, speed, frame, type of guidance, type of booster and type of warhead. Data on the deployment of missiles and the name of the prime contractor for the project, i. e., the corporation which handles the main contract, will serve to characterize the system more fully.

The Army missiles are in the surface-to-air and surface-to-surface category; the Navy and the Air Force have missiles in the surface-to-air, surface-to-surface, air-to-surface and air-to-air categories. The majority of the Army

missiles fall under the heading of "tactical"; the Air Force missiles have longer range and are used for strategic rather than tactical purposes.

ACCEPTED PRINCIPLES OF DESIGNATION

In the United States each missile is supplied with a code name (Minuteman, Pershing, Sergeant, etc.) and a special designation worked out by the US Department of Defense.

The complex system of designation of missiles and rockets is described below. [1]

Designations for Vehicle Types

Letter	Title	Description
G	Booster	A vehicle employed to launch and/or propel other aerospace vehicles
J	Spacecraft	A vehicle designed primarily to operate in space
M	Missile	A heavier-than-air vehicle with a capability of traveling within or outside the earth's atmosphere whose trajectory or flight path may be controlled by installed or remote control mechanisms and which is not designed for human occupancy.
P	Probe	An instrumented vehicle used to penetrate the aerospace environment and report back information
R	Rocket	A non-guided missile
S	Satellite	An aerospace vehicle designed to orbit

Designations for Missile Launching Environments

Letter	Title	Description
A	Aircraft	Aircraft-launched
C	Coffin	Horizontally stored in protective enclosure

[1] Missiles And Rockets, Sept. 25, 1961

Continued

Letter	Title	Description
G	Ground Vehicle	Launched from a ground vehicle other than a railroad car
H	Silo	Vertically stored and protected below ground level
L	Silo Launch	Launched from a silo
M	Multiple Launch	Capable of being launched from more than one environment. Applicable only when type, model and series are identical
P	Soft Pad	Stored on unprotected pad and launched above ground
R	Railroad Car	Launched from railroad car
S	Space	Launched from aerospace vehicle in space

Designations for Missions of Missiles and Spacecraft

Letter	Title	Description
B	Communication	Designed to receive, transmit, relay or reflect electromagnetic impulses
C	Cargo and Logistic Support	Designed to transport materiel and personnel
E	Early Warning	Designed to provide early warning of attack
I	Intercept-Defense	Designed to be employed in Air Force defense missions
K	Tanker	Designed to provide in-flight refueling of other vehicles
N	Test	Designed primarily for the purpose of testing vehicle design of a new or radical nature
P	Propulsion	Designed to launch space vehicles and/or place them in orbit
Q	Target	A guided missile employed in Air Force target missions
R	Reconnaissance	Designed for use in Air Force reconnaissance missions
S	Strategic	Employed in Air Force strategic missions
W	Weather	Designed for weather observation and reporting
X	Research	Designed to explore and study the elements in the outer atmosphere and space

Model numbers for missiles run in a consecutive sequence beginning with "1." Model numbers for spacecraft space vehicles run in a consecutive sequence beginning with "101."

Thus, the designation for a spacecraft interceptor could be IJ-101. The designation for a truck-launched ICBM could be GSM-1.

* * *

Basic performance data on the US Armed Forces missiles and rockets given below will serve to characterize those systems which are already operational as well as those which are in the research and development stage.

STRATEGIC MISSILES

Minuteman (LGM-30A, B, F) (Air Force)

Type: ICBM

Status: A & B operational, F, operational systems development

Major contractor: Boeing Co., major contractor and systems integrator

Frame type & configuration: Three-stage; length, A, 53. 7 ft.; B, 55.9 ft.; F, 59.8 ft.; diameter at interstage junction, 6.2 ft.; weight, 65,000 lbs.

Propulsion type: Solid propellant

Guidance type: All-inertial

Payload: Nuclear warhead

Performance: Range, 6,000-7,000 n. mi.; speed, over 15,000 mph; apogee, 700 mi.; reaction time, 32 sec.; target selection time, less than 10 sec.; yield, about one megaton

Polaris (UGM-27 A, B, C) (Navy)

Type: Surface-to-surface strategic missile fired from submerged submarines

Status: All three versions operational

Prime contractor: Lockheed

Frame type & configuration: A-1 length, 28.5 ft.; diameter 4.5 ft.; weight, 28,000 lbs.; A-2 & A-3 length, 31 ft.; diameter, 4.5 ft.; weight, 30,000 lbs.

Propulsion type: Solid

Guidance type: All-inertial
Payload: Nuclear warhead, about one megaton
Performance: Range A-1, 1,200 n. mi.; A-2, 1,500 n. mi.; A-3, 2,500 n. mi.; speed, about 8,000 mph

Titan II (LGM-25C) (Air Force)

Type: ICBM
Status: Operational
Prime contractor: Martin Denver
Frame type & configuration: Length, 103 ft.; diameter, 10 ft.; weight, 330,000 lbs.
Propulsion type: Liquid propellants, nitrogen tetroxide and a 50/50 mixture of hydrazine; two engines first stage, one engine second stage; 430,000 lbs. thrust first stage; 100,000 lbs. thrust second stage
Guidance type: Inertial
Payload: Nuclear warhead; about 20 megatons
Performance: Range, over 6,300 n. mi.; speed, over 16,000 mph

TACTICAL MISSILES

Pershing (Army)

Type: Two-stage ballistic missile
Status: Operational
Prime contractor: Martin/Orlando
Frame configuration: Length, 34.6 ft.; diameter, 40 in.; weight, 10,000 lbs.
Propulsion type: Two-stage solid propellant
Guidance type: Inertial
Payload: Nuclear warhead
Performance: Range, 100-400 n. mi.; speed, supersonic

Sergeant (MGM-29A) (Army)

Type: Single-stage ballistic missile
Status: Operational
Prime contractor: Sperry Utah Co.
Frame configuration: Length, 34.5 ft.; diameter, 31 in.; weight, 10,000 lbs.
Propulsion type: Single-stage solid-propellant, employs drag brakes to control range

Guidance type: Inertial
Payload: Nuclear warhead
Performance: Range 25—75 n. mi.; speed, supersonic

Honest John (MGR-1) (Army)

Type: Surface-to-surface rocket
Status: Operational
Prime contractor: Douglas
Frame type & configuration: Length, 24.8 ft.; diameter, 30 in.; weight, 4,500 lbs.
Propulsion type: Single-stage solid propellant
Guidance type: Free-flight, spinstabilized
Payload: Nuclear or high-explosive warhead
Performance: Range, 12 mi.; speed, Mach 1.7

Little John (MGR-3A) (Army)

Type: Support of airborne operations
Status: Operational
Prime contractor: Emerson Electric Co./Consolidated Western Steel
Frame type & configuration: Steel & aluminum; length, 14.5 ft.; diameter, 12.4 in.; weight, 800 lbs.
Propulsion contractor: Hercules
Propulsion type: Solid propellant
Guidance type: Free-flight
Payload: Nuclear or high-explosive warhead
Performance: Range, over 10 mi.; speed, supersonic

Lance (XMGM-52) (Army)

Type: Surface-to-surface Division support missile
Status: Engineering development
Prime contractor: LTV Michigan Div.
Propulsion type: Prepackaged storable liquid rocket
Guidance type: Modified inertial
Payload: Primarily an improved (bomblet) high-explosive warhead; nuclear warhead can be used against hard targets; also has chemical capability
Performance: Range between 3 and 30 miles; very lightweight system with great mobility

Davy Crockett (Army)

Type: Surface-to-surface tactical nuclear support weapon
Status: Operational
Prime contractor: In-house
Frame type & configuration: Bulbous, 279-mm super caliber projectile fired from either 120-mm or 155-mm recoilless rifle through adapter pistons
Propulsion type: Solid propellant
Guidance type: Free-flight
Payload: Sub-kiloton nuclear warhead
Performance: Classified

ANTI-TANK MISSILES

Entac (MGM-32A) (Army)

Type: Anti-tank missile
Status: Operational
Prime contractor: Nord Aviation
Frame configuration: Length, 32 in.; diameter, 5.5 in.; weight, 37 lbs. with launcher, 27 lbs. without launcher
Propulsion type: Solid
Guidance type: Wire-guided
Payload: High-explosive shaped charge
Performance: 6,600-ft. range; speed about 180 mph

Tow (Army)

Type: Anti-tank missile
Status: Engineering development
Prime contractor: Hughes
Frame type & configuration: Tube-launched, optically-tracked, wire-guided; system total weight, 160 lbs.
Propulsion type: 2-stage solid propellant — one charge to eject round from launch tube before second motor ignites
Guidance type: Wire-guided through a link in the optical sight
Payload: High-explosive warhead

SS-10 (Army)

Type: Surface-to-surface anti-tank missile
Status: Operational, being replaced by Entac
Prime contractor: Nord Aviation, prime
Frame type & configuration: Length, 34 in.; diameter, 6 in.; wingspan, 30 in.; weight, 33 lbs.; cruciform wings
Propulsion type: Solid propellant
Guidance type: Wire-guided
Payload: High-explosive shaped charge
Performance: Range, 1,600 yds.; speed, 180 mph

Shillelagh (MGM-51A) (Army)

Type: Tactical guided missile for infantry support
Status: Operational evaluation
Prime contractor: Philco Aeronutronic
Frame configuration: Diameter, 152 mm; weight, 40 lbs.
Propulsion type: Solid propellant
Guidance type: Command
Payload: High-explosive warhead
Ground equipment contractors: Cadillac Motor Div., General Motors, supplies the General Sheridan armored reconnaissance, airborne assault vehicle armed with Shillelagh; Chrysler supplies M-60 tank, which is also to be armed with Shillelagh in connection with development of a new low-silhouette tank turret
Performance: Classified

MAW (Army)

Type: Surface-to-surface anti-tank weapon
Status: Program definition
Prime contractor: (Two versions still competing) McDonnell, wire-guided version; Army Missile Command, free rotor gyro version
Range: 500-1,550 yds.

M72 (Army)

Type: Anti-tank
Status: Operational
Prime contractor: Hesse-Eastern Div., Flightex Fabrics, Inc.

Frame type & configuration: Length, 25 in.; diameter, 3 in.; weight, 4.5 lbs.
Propulsion type: Solid propellant, which burns out before rocket leaves launch tube
Guidance type: Free-flight, finstabilized
Payload: "Octol" high-explosive warhead
Performance: Range, 500 yds.
Remarks: Carrying tube serves as disposable launcher; replaces rifle grenades and 3,5-in. rocket launcher; formerly called LAW (light anti-tank weapon); useful against tanks, pillboxes and other hard-point targets

AIR/SPACE DEFENSE MISSILES

Hawk (MIM-23A) (Army)

Type: Surface-to-air defense missile against low-flying planes
Status: Operational
Prime contractor: Raytheon
Frame type & configuration: Length, 16.8 ft.; diameter, 14 in.; weight, 1,275 lbs.
Propulsion type: Solid propellant, dual stage
Guidance type: Semi-active radar homing
Payload: High-explosive warhead
Performance: Range, 22 mi.; speed, supersonic; ceiling, 100 to 45,000 ft.

Nike-Hercules (MIM-14B) (Army)

Type: Surface-to-air air defense missile
Status: Operational
Prime contractor: Western Electric
Frame type & configuration: Length, 41 ft.; diameter, 31.5 in.; weight, 10,000 lbs.
Propulsion contractor: Thiokol
Propulsion type: Two-stage solid propellant
Guidance type: Command; system uses low-power acquisition, high-power acquisition, target-tracking, and missile-tracking radars in conjunction with electronic data-processing gear
Payload: Nuclear warhead
Performance: Range, over 75 n. mi.; ceiling, 100,000 ft.; speed, over Mach 3

Nike-X (Army)

Type: Dual-missile (Zeus and Sprint) A-ICBM/SLBM system

Status: Development

Prime contractor: Western Electric; Bell Laboratories, design and development

Frame type & configuration: Douglas, Zeus frame; Martin-Orlando, Sprint frame; Sprint is smaller than Zeus

Propulsion type: Solid propellants for three Zeus stages, two Sprint stages

Guidance type: Command; will use MAR (multi-function array radar) instead of three separate radars for target acquisition, tracking and discrimination; missile site radar (MSR) will track and control more than one defensive missile at a time

Payload: Nuclear warheads for both Zeus and Sprint

Performance: Zeus — range, over 200 n. mi.; speed, over Mach 4; Sprint — shorter in range than Zeus but with acceleration well in excess of 100 g

Sprint (Nike-X System) (Army)

Type: Surface-to-air A-ICBM/SLBM missile

Status: Development

Prime contractor: Martin

Frame type & configuration: Smaller than Nike-Zeus; two-stage, length, 27 ft.; diameter at base 4.5 ft.; missile is conical

Propulsion contractor: Hercules/Lockheed

Propulsion type: Solid propellant; extremely high acceleration

Guidance contractor: Western Electric

Guidance type: Command; will be mixed with Zeus missiles in batteries controlled by multi-function array radar (MAR) and missile site radar (MSR); components must withstand tremendous g forces

Payload: Nuclear warhead

Performance: Range, classified; speed, classified; acceleration, extremely high

Zeus (Nike-X System) (Army)

Type: Surface-to-air A-ICBM
Status: Advanced development as part of Nike-X
Prime contractor: Western Electric
Frame type & configuration: Length, 48.3 ft.; diameter, (sustainer) 36 in.; fin span, 10 ft.; launch weight, 22,800 lbs.
Propulsion type: Three-stage solid propellant, with "jet-head" system for maneuvering in space; acceleration very high
Guidance type: Command; system uses MAR and MSR acquisition radar in conjunction with ultra-high-speed electronic data-processing gear
Payload: Nuclear warhead
Performance: Slant range, about 200 n. mi.; speed over Mach 4
Remarks: Missile has become part of the Nike-X missile "mix;" third-stage components have been repackaged and a more powerful booster added

Redeye (MIM-43) (Army and Marines)

Type: Shoulder-fired anti-aircraft missile
Status: Production
Prime contractor: General Dynamics/Pomona
Frame type & configuration: Bazooka-type, wingless cylindrical weapon; length, 48 in.; diameter, 2.75 in.; weight, 28 lbs.
Propulsion contractor: Atlantic Research
Propulsion type: Dual-stage solid propellant
Guidance contractor: Philco/General Dynamics/Pomona
Guidance type: Infrared
Payload: High-explosive warhead
Performance: Range, classified; speed, supersonic

Section VIII

MILITARY ROCKET AND MISSILE SYSTEMS

WEAPON SYSTEM CONCEPT

Definition of the Weapon System. The weapon system consists of the missile and all the required equipment and support which will permit the missile to meet prescribed

reliability, accuracy and availability requirements for the purpose of carrying a payload to the target. To achieve these aims the following main subsystems must be developed: the missile, the ground operating equipment, the ground support equipment, maintenance, logistics, facilities, communications.

Ground Operating Equipment (GOE). The ground operating equipment as opposed to ground support equipment is defined as that equipment which does not fly, but is required in order to launch the missile. It consists of launch control equipment, launch consoles, electrical equipment and various cabling devices, elevation equipment or booms, umbilicals, power equipment, propellant loading system and any of the required utilities.

Ground Support Equipment (GSE). The ground support equipment is the equipment which is required to test, maintain, handle, repair, and support the missile but which is not necessary to actually launch it. For example, checkout equipment is required for proper operation of a missile battalion or a squadron. However during the actual countdown, the missile can be launched without it, providing the missile is in readiness. Other GSE includes missile handling trailers, cranes, liquid oxygen tankers, liquid nitrogen trailers, component testing equipment, liquid oxygen plants, handling equipment and repair equipment.

Maintenance. Fundamentally, the area of maintenance is probably as important as any of the other areas noted. When manning a squadron, a greater number of people will be performing the maintenance task than performing the operational tasks. The missile as opposed to the airplane sits on the ground 100 per cent of the time and is launched only in time of war. Therefore the problem becomes not one of operation, as in the sense of operating an aircraft, but of maintenance of the missile.

Logistics. Logistics is the supply and resupply of all possible requirements of a squadron.

Facilities. There are two kinds of facilities — operational facilities and support facilities. The operational facilities are those which will protect the missile from the effects of weather and nuclear explosions and which will aid in launching the missile. The silo launcher and the launch operations building are operational facilities. The

operations building protects the launch consoles, status panels and monitoring panels. Support facilities include roads, utilities, security fencing, munitions buildings and maintenance buildings. They are needed in the support of the missile but are not required for the actual launching of the missile. The facilities which receive the most attention are the launcher facilities. These can range from a shelter which protects an otherwise exposed missile against inclement weather to those which are very strong and placed below ground to protect the missile against a near-miss enemy nuclear burst.

Communications. Communications is one of the most complex areas within the support activity. Through the processes of communications a launch is accomplished, and possibly just as important, a launch can be prevented. It is therefore essential to have two or more separate, highly reliable and well protected communication techniques available between any two points in a squadron. These may be microwave, dial phones, or public address systems.

The cost of a fixed missile system may be assumed to be as follows: Missile, 15 per cent; Support Equipment, 45 per cent; Support Facilities, 40 per cent. The operating cost may be assumed to be proportional to the number of personnel required to launch and support the weapon system.

A weapon system is characterized by what is known as "operational concepts." These concepts listed below are:

Survivability (Hardness, Dispersal)
Maintenance
Reaction Time
Environmental Protection
Weapons Effects
Readiness
Firing and Targeting
Safety and Hazards
Squadron Configuration
Independence
Manning and Training

Survivability is determined by the hardness of a site and the dispersal of a number of sites. Hardness is defined as the capability of the launch site and its equipment to withstand the overpressures of a nuclear blast. The specific hardness of a site is a function of the overpressure it can withstand and still launch a missile.

Dispersal is defined as the placement of sites to prevent multiple destruction by a single enemy warhead. Hardness and dispersal are two parameters of survivability. It is not the established inventory of missiles in a guided missile force which is important. It is the number available after an enemy attack.

Reaction time is the time required to launch a missile after the initial order is received. This could be from two minutes to two hours.

The readiness concept involves the determination of how and at what levels all missiles must be maintained to meet a certain specified countdown. For example it might be necessary to launch all possible missiles immediately at a salvo. This is the ultimate readiness where only the reaction time stands between the order and the execution. There are however quite a number of states of readiness of the missiles, ranging from ultimate readiness to missiles in storage in a depot, requiring days to make ready for launching.

In the firing of missiles it is necessary to determine the launching order and method. The missiles might be fired as a salvo or ripple-fired. It is also important to anticipate the need for changing targets. Targeting of a long range missile is quite complex and the capability of fast targeting changes may be beyond the scope of the available guidance system.

Squadron configuration is the physical arrangement of the squadron. It is important to determine the effects on the squadron of isolating launchers or grouping them together. In either case the hardness and survivability to enemy attack must be balanced against costs, equipment, logistics, manning and maintenance requirements.

The sum-total of the operational concepts characterizes the level of reliability of the system.

The selection of the optimum level of reliability is of paramount importance. The design reliability of a missile is a function of time and costs. It may take a comparatively short time to reach 80 or 90 per cent reliability and an infinitely longer time to achieve 99 per cent reliability. The most important aspect by reliability is to know its exact value at whatever level is attained rather than to strive for the highest possible level.

Life of a System

Phase	Time of years								
	0	1	2	3	4	5	6	7	8
need	A								
ideas		B							
mockup			C						
sample system				D					
operational system					E	E	E	E	
outmoded system									F

STRATEGIC WEAPON SYSTEMS: THE MINUTEMAN, THE POLARIS

The Minuteman (ICBM). Solid-propellant rockets of intercontinental range considerably simpler in construction than liquid-propellant types store well and need little handling and maintenance. Moreover, solid-propellant engines can start in seconds. Powerful solid-propellant engines; stability of combustion, burnout timing, and protection of combustion chamber walls from excessive heat are only some of the problems with which the experts of solid-propellant rockets saw themselves confronted. Broad requirement for "solid generation" ICBM are: a range of 5,500 n. mi.; launching from hardened launching pits or rail cars; three stages; solid propellant; storability several months and, if possible, much more; thrust vector control with swiveling jets; and inertial guidance. The Minuteman has been developed to meet these requirements. It is a 3-stage solid-propellant intercontinental ballistic missile (Fig. 12) with a mission to destroy strategic targets. The missile will be launched from underground tubes.

Existing engine design configurations for first- and second-stage engines consist of forged cylindrical sections of heat-treat steel, welded at the joints. Forward and aft end domes also are forged from high-heat-treat steel. The forward domes are welded to the cylindrical section. The aft domes are attached by threads for Stage 1 and by studs for Stage 2.

The third-stage engine is fabricated from filament-wound fiberglass which results in an excellent strength-

to-weight ratio. A pound of structural weight saved on the third stage affects range by a factor of approximately 4 compared with the second stage and approximately 16 compared with the first stage.

Fig. 12. Intercontinental ballistic missile Minuteman.

The major nonpropulsive structural components of the Minuteman vehicle are the first-stage skirt attached to the aft end of the first-stage engine; two interstage structures tying the first-, second-, and third-stage engines together; the warhead section; and the guidance and control section.

The skirt serves a threefold purpose. It helps impart aerodynamic stability to the missile during the critical

which is also necessary for prelaunching checks and launch release.

A transmission system taking advantage of the conductivity of the earth itself consists of special subterranean antenna which send out electromagnetic waves, these are deflected at the earth's surface, pass along it, and are finally received by forther subterranean antennas located several miles away.

The Polaris (IRBM). The Polaris is a solid-propellant medium-range ballistic missile, launched from submarines in submerged position.

The first and second stage engines have four nozzles each, the thrust vectors of which can be swiveled for controlling the missile by means of jet deflection rings.

Thrust of first stage engine: approx. 55,000 lbs.

Solid fuel: Polyurethane perchlorate with aluminum additive.

The inertial guidance system is understood to direct the missile on the target area with such accuracy that the warhead's average deviation from target is not more than a few hundred yards.

The re-entry body, carries a nuclear warhead with an explosive effect of about a megaton. During launching and flight through the earth's atmosphere, the nose cone remains covered by an extremely hard and highly insulated material which does not ablate until re-entry into the denser air layers.

The basic concept of the Polaris allows of further development.

Plans are in existance for increasing the range to 1,500 n. mi. (Version A-2) and to 2,500 n. mi. (Version A-3).

Should a mobile land version of the Polaris be adopted the weapon together with its fire control system, signals equipment, and launching gear could be mounted on one semitrailer. These vehicles would be able to move on first and second class roads [1], and could find separated points from which to operate. Systems for the maintenance, inspection, and overhaul of the weapons system will have to be set up at certain places. Whilst on the move,

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[1] First and second class roads are those with hard (usually concrete) pavement.

the missile unit would maintain permanent communication with its command and control base. The weapon could be ready to launch a few minutes after receipt of the order to do so.

TACTICAL WEAPON SYSTEMS: THE PERSHING, THE SERGEANT, THE LITTLE JOHN, THE HONEST JOHN, THE DAVY CROCKETT, THE SHILLELAGH, THE M72, THE ENTAC, THE REDEYE

At the beginning of the fifties the US Army had at its disposal the Redstone with its range of 200 miles, the

Fig. 14. Firing preparation of the Pershing missile.

smaller Corporal with a range of 75 miles and the Honest John short-range artillery rocket. Today a number of guided missile for different purposes have been produced.

What are these new US Army guided missiles like and how are they operated?

The longer-range guided rocket systems are the Sergeant and Pershing, both with 20 kiloton warheads.

The Pershing (Fig. 14) is a selective range ballistic missile. All portions of the weapons system have been made air-portable, fully mobile on the ground and smaller and simpler than the corresponding parts of the Redstone system. The missile itself is powered by tandem solid motors, the first stage having high impulse composite propellant and a single nozzle with jet deflection.

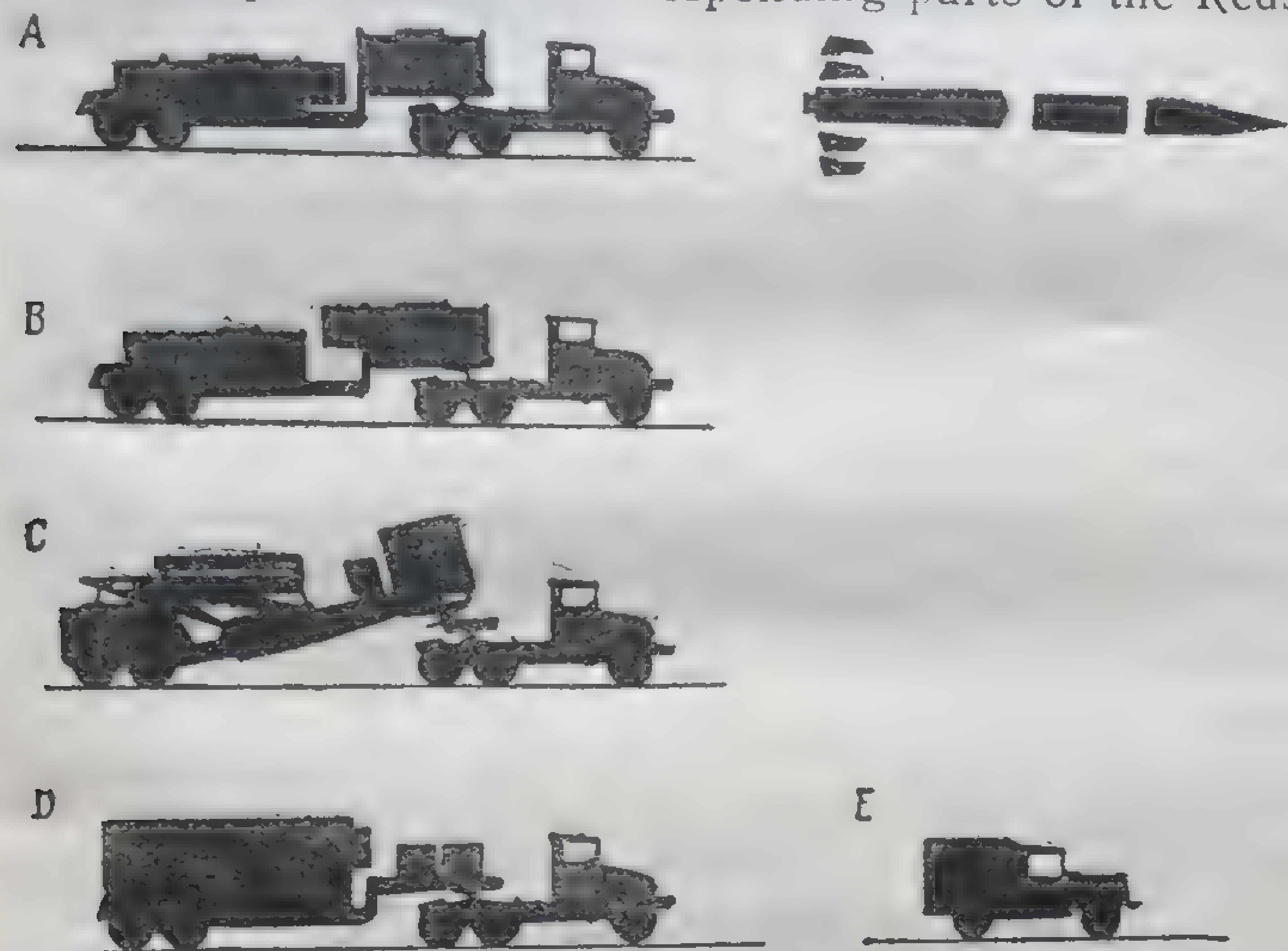

Fig. 15. Transporting of the main subassemblies of the Sergeant weapon system:

A — transport vehicle for tail section (missile motor), center section (guidance system) and control surfaces; *B* — transport vehicle for two nose cones (nuclear warhead); *C* — launcher with fire set; *D* — test station with maintenance equipment and spares; *E* — radio vehicle.

Ahead of these tandem propulsion sections is a bay containing the pure-inertial guidance system and on the front of the weapon is the pointed nose and nuclear warhead. Trajectory control is assisted by powered delta fins and by large rectangular surfaces at the rear of the second stage.

A complete Pershing battery is transported on four tracked vehicles. One carries the missile, minus warhead

on its transporter-erector-launcher (TEL); the second carries the warhead and azimuth-laying equipment, the third is filled with communications gear and the fourth houses the fire control unit and power pack. When the firing site has been reached the TEL lowers the launcher, hinged to the outriggers at the rear, to form a simple ring levelled by three vertical legs and rotating in azimuth. The second vehicle backs up to the first for the attachment of the warhead and the complete missile is than elevated vertically over the launcher. The TEL has four pneumatic tires to enable it to be maneuvered independently of the vehicle. After the short erector arm has been lowered the missile stands alone except for the reusable umbilical mast.

The Sergeant is a tactical ballistic missile for mobile deployment. All portions of the system are mounted on standard prime movers (Fig. 15), communication equipment being mounted on a four-wheel truck and the remainder being carried on articulated trailers with three-axle tugs. One transporter carries the motor with 6,000 lbs. of polysulphide composite propellant, cast in its steel case, the inertial guidance section and the four fins each with a trailing edge control surface linked to a refractory deflector in the propulsive jet; the fins are carried in individual flat packages and the motor and guidance in light alloy cylindrical containers. Another transporter carries two warhead packages and the system is completed by the field maintenance test station, organizational maintenance test station and launching station. The latter carries the folding launcher, fabricated from new high-strength steels, an azimuth orientation set, a gas turbine, generator and a firing set which serves as a data clearance center.

Emplacement starts merely by pulling off the road to a suitable location and deploying the vehicles (Fig. 16). The launcher tug is uncoupled, the generator set started, the outriggers positioned and the chassis leveled. Then the launcher superstructure is raised and the launching boom unfolded to provide the girder on which the sections of the missiles are hung for assembly. First the motor is brought up, its container opened and complete unit hoisted up and attached to the launching hooks. Next the guidance section is hoisted and rolled back for mating to

the motor, after which the trolley, from which it was suspended is removed, the weapon is completed by adding the warhead with electrical connectors, and attaching the

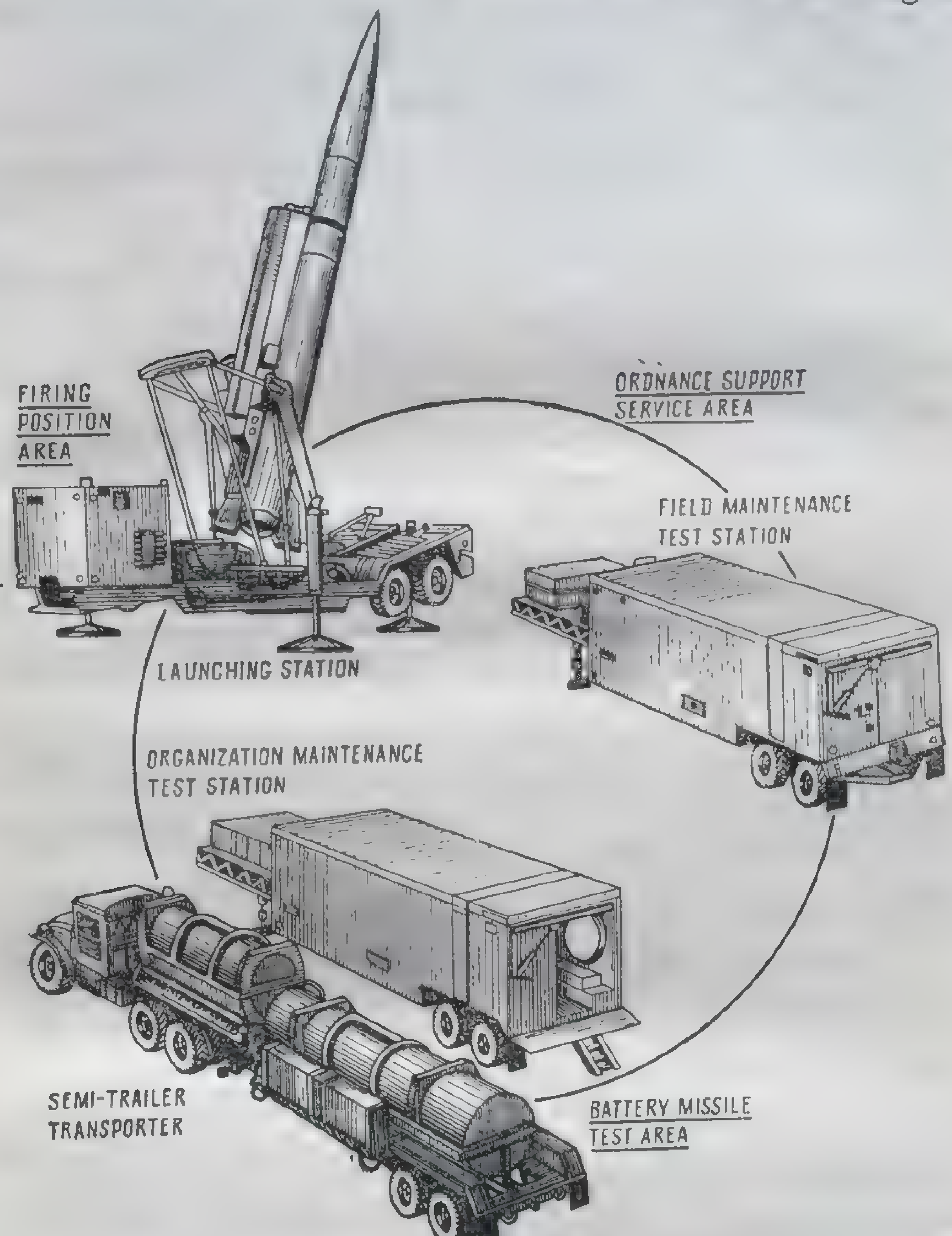

Fig. 16. Deployment of the Sergeant weapon system.

four interchangeable fins. Target data are fed to the firing set, together with launcher position, warhead instructions and meteorological information and the countdown is entirely automatic, the launcher adopting the correct azimuth and elevation shortly before firing.

The countdown, from the time the missile is assembled, requires 44 minutes. Sequence is approximately as follows:

T—44: firing set energized for preheat, firing box tested and emplaced, transfer switches turned to "self test."

T—39: power on, self test begun, firing data parameters inserted and computed.

T—35: self test completed, fire mission computed and checked.

T—30: required parameters readout and program cleared.

(Before T—30, a hold can be called at any time and maintained indefinitely; at T—20, battery can hold for several days.)

T—20: begin automatic countdown and start program.

T—19: insert first block of parameters.

T—12 1/2: insert and check random readings.

T—7 1/2: insert second block of parameters.

T—3 1/2: check flight parameter computations.

T—3: assume remote firing control.

T—0: missille fires automatically, barring operator override.

Automatic holds dictated by sensing circuits stop the launch programer and require resetting to T—20. Command hold can be called at any time and require resetting based on the following limits:

T—7 1/2: hold for variable time depending on motor temperature and other sensitive subsystems.

T—90 sec.: hold for 10 minutes.

T — 20 to T — 0 sec.: hold for 2 minutes.

Time on target is approximately the countdown sequence time plus 90 sec.

The weapon system has been designed for air transportation and deployment in all types of terrain and environmental condition.

Leaving aside these longer-range guided rockets such as the Sergeant and Pershing (with 20-kiloton warheads), the ground forces' tactical guided missiles fall into the following main categories.

1. Artillery rockets for the support of front-line troops. These weapons are generally intended for use in the vicinity of the combat units themselves and must therefore be highly mobile; they operate under the most severe con-

ditions, such as those characteristic of a nuclear battlefield. Their range is between 6 and 200 miles, and they are transported and operated by four to six men. Typical examples are the Little John and Honest John unguided artillery rockets, and the multipurpose Lance.

2. One- and two-man weapons for antitank operations and operations against fortified positions. These weapons, which are designed for front-line operations, have ranges of 1,000 to 5,000 yards and can be transported by infantrymen or on light vehicles and trailers. Typical representatives of this category are the French SS-10 and SS-11, the M72, and the Davy Crockett unguided nuclear rocket.

3. Rockets for the destruction of low-flying strike aircraft and tactical guided missiles. These weapons, which operate over shorter ranges, must be largely self-contained, i. e., they must have their own detection, target tracking and guidance radar, and must be highly mobile and ready for launching at any time in order to give the army units which they support effective protection against attacks from the air. Typical representative is the Hawk anti-aircraft rocket.

4. One-man anti-aircraft weapons for operations against low-flying front-line aircraft. This is a task which was formerly the province of light-caliber machine guns. The sole representative of this category is the US Army's Redeye, with infrared homing head, which can be fired from a shoulder launching tube.

Air Force, too, will be equipped with special weapons for use against tanks, fortified positions and tactical radars.

Unlike the 100 mile range Sergeant and the Pershing with its range of 300 miles, which require a number of vehicles to transport the weapons and their ground support equipment, most of the tactical missiles can be transported by a single vehicle or even by an infantryman and can be fired immediately without appreciable preparation.

To fire the *Little John* and *Honest John* unguided artillery rockets, however, the missile crew must have precise information on the position of the target, before they train the launchers onto it. The Honest John is operational with the US Army in Europe and Japan and with the fighting forces of a number of NATO States and can

transport a 1,500 lbs. conventional or nuclear warhead over a distance of 12 miles. The Honest John is fired from a heavy multi-axle launcher, but the Little John can be launched from a relatively light single-axle launcher which can be attached to a variety of army vehicles. The Little John and its launcher, together with the remaining ground support equipment, weigh some 2,500 lbs. and can be transported by helicopter. The unguided Little John and Honest John are nuclear warhead carriers of "moderate" accuracy for operations against dispersed targets.

The simplest nuclear rocket in the US Army so far is the *Davy Crockett*. Powered by a solid-propellant motor and spin-stabilized by unfolding fins, it can attack targets at distances of up to 5 miles, traveling on a relatively flat trajectory. The US Army Ordnance Corps, has developed two launching systems, both consisting of a tube for recoilless firing, though one is slightly heavier and has an additional charge to accelerate the missile from the tube. This will increase the Davy Crockett's range over the normal 5 miles. Both launching devices can be transported on jeeps, antitank vehicles or other small vehicles, and can be operated by two men. The smaller Davy Crockett launcher can actually be carried and set up by two men.

A small guided weapon, named *Shillelagh*, can be fitted with a nuclear warhead for operations against armored vehicles, troop concentrations and fortified positions. With a weight of 45 lbs. and a caliber of 90 mm, the Shillelagh is fired from a simple launching tube and is then guided to its target by a microwave radio guide beam aligned with the aiming device.

Little is yet published of the new *M72* anti-tank weapon. It is aimed at the tank by means of an optical sight and is spin-stabilized by fins which open as it begins its flight. The telescoping launching tube can be extended before firing, to give the weapon greater directional accuracy. The missile is remarkable for its small dimensions and the low weight of the explosive charge (only a few pounds).

The French-designed and produced *Entac* anti-tank missile is a light-weight, wire-guided missile employing a shaped charge high explosive warhead. Credited with a range capability of over 2,000 meters, the missile has

a launch weight of 37 pounds. Overall weight with container is 80 pounds. A battery of eight missiles can be mounted on a 1/4-ton truck and three additional Entac's can be carried on a trailer pulled by the same vehicle. Normally a two-man crew is used to fire the weapon. Each missile is 0.83 meters in length and has a wing span of 0.38. Speed of the missile at burnout is 305 kilometers per hour.

The Redeye, a 4 ft. rocket with infrared homing head, can be fired from a simple, light launching tube which also serves as transport container. This one-man weapon is designed primarily for defense against low-flying fighter-bombers and reconnaissance aircraft, but its homing device enables it to detect and destroy other heat sources such as vehicles, diesel power units, etc.

Section IX

TENDENCIES OF DEVELOPMENT: STRATEGIC SYSTEMS

THE GENERAL TREND

Product improvement — rather than development of completely new systems — is the outlook for Strategic Forces during the foreseeable future.

Major new systems requiring the development of a complete new weapon will not be required.

As far as a weapons system is concerned, the US is still in the middle of Minuteman. The development testing and operational testing of Wing VI (Minuteman II) are just being started.

Meanwhile, two important product-improvement decisions have already been made with regard to the Minuteman II:

— improvements will be made in the guidance and control system to significantly improve the initial system's accuracy;

— an improved re-entry vehicle enabling the Minuteman to penetrate defense will be introduced into the program within several years. The re-entry vehicle is the Mark XII.

Minuteman II missiles will be back-fitted into the first five wings, and the entire Minuteman system will be modernized.

ACCURACY

Accuracy of both Minuteman and Polaris has been improving. Further improvements are possible in the present guidance and control systems without developing an entire new system.

Future guidance schemes are under consideration, however, and development of components is being funded. These developments fall into four major areas:

— inertial guidance during boost;
— inertial all the way;
— inertial and terminal guidance; and,
— inertial and radio vernier.

A great deal of interest and emphasis is being placed on the inertial-with-terminal-correction capability. The main problem with the maneuvering re-entry vehicle, however, is that the guidance components must be able to withstand the high acceleration forces encountered in coming back into the atmosphere. Terminal schemes will have to wait until the possibilities of improving internal systems in present systems have been exhausted.

GETTING THROUGH

One of the biggest missile R&D [1] programs is the Advanced Ballistic Re-entry Systems (ABRES) program to insure that ballistic missiles will be able to penetrate defensive systems they encounter. Development of re-entry vehicles for operational systems does not fall under this program, but rather is funded under the specific system.

Progress has been made in improving knowledge of the physical effects resulting from a warhead re-entering the atmosphere and of the methods with which to simulate these effects and penetration-aid packages are becoming available.

Possible penetration techniques under development include reducing the vehicle's cross section so that it becomes "invisible" to the enemy's sensors whether they be radar, infrared or optical.

[1] R&D — Research and Development.

The next area of interest is the active devices — such as chaff or electronic countermeasures packages — which obscure the re-entry vehicle. Decoys which have the same reflective characteristics as the re-entry vehicle can also be used. However, once the re-entry vehicle penetrates the atmosphere these decoys are quickly separated from the warhead, thus relieving the discrimination problem.

Two final areas of interest are: 1) hardening of warheads so that they can withstand the defensive weapon effects and 2) using multiple warheads to saturate the defenses so that the enemy cannot react fast enough to destroy all the re-entry vehicles.

Terminal guidance would increase penetrability considerable by increasing the threat tube — the theoretical volume within which a re-entry vehicle must approach in order to destroy a target — by targeting the re-entry body to fall short of the target, and then through a terminal maneuver pulling it up and into the target. This is a further dividend — quite apart from increased accuracy — accruing from maneuvering re-entry bodies.

COMMAND AND CONTROL

This topic, an integral and important part of the strategic forces, still causes concern, although certain advances are claimed to have been made. The area of main concern is the need for, and extent of, a post-attack command and control system.

Two of the major improvements being made in command and control of the strategic forces are the integration of Minuteman I and II into a single system and the new fire control system being introduced into Polaris submarines.

Minuteman effectiveness will be stepped up through the internetting of the I and II missile communications system — thus enhancing the targeting flexibility of the entire force. The Polaris fire control system will also improve the targeting capabilities of each submarine. Minuteman flexibility will give it a greater choice in the selection of pre-assigned targets, as well as the capability of being launched on command from an airborne command post.

Dependability is a broader term than just reliability. It includes reliability (incidence of mechanical malfunction), as well as readiness, survivability and penetration.

Section X

TENDENCIES OF DEVELOPMENT: TACTICAL SYSTEMS

The official US sources consider that despite the fact that several billion dollars have already been spent for the tactical research and development the major efforts are still to be made. The existing tactical systems in the ground-to-ground, ground-to-air, and air-to-ground categories (as well as those in the sea-to-ground, sea-to-air, air-to-sea categories) are not deemed satisfactory by the field experts.

KEY ISSUE

At present, the most pressing problem is target acquisition. Whether the assignment is antitank operations or locating and destroying enemy troop units, the problem of "where is the target" looms up. Certain progress has been made but there is still room for creative ideas.

Target acquisition and target handling, involving the identification as well as location of the enemy, has been a major problem and promises to get no easier in the future. It may be that the answer lies in the integration of multi-sensor information and the use of advanced pattern recognition techniques.

A second problem is one of selflocation: the need for mobile forces to locate themselves in relative coordinates with very small errors. This is essential for re-supply, fire direction and command. Equally essential is the ability of the unit to do this in real time.

In the ordnance and fire control area, the question is basically "once acquired, how can we engage targets without exposing our own weapons launch site?"

This is especially critical to anti-tank weapons. A cardinal rule for tank commanders is that they must travel

in pairs. Hence the anti-tank gunner is put at a fatal disadvantage even if he has a first-round hit, since the recoil of his weapon reveals his position.

It is even worse when the gunner must keep the missile on target for 10 seconds.

Simple, rugged, reliable anti-tank weapons for the infantry have been firm requirements for some time. Work has been done on terminal homing systems and it may be that a terminal homing weapon will answer the problem. Indeed, it may be that the next ten years will see such improvement in accuracy and reliability that a major effect in tactics will occur.

COMMAND AND CONTROL

One of the most difficult aspects of tactical war is command and control. And of all the command and control (C&C) challenges the most severe is the closer integration of ground and air forces for all missions: close support, interdiction, anti-tank operations and reconnaissance.

One part of this problem is the marriage of aircraft and missiles with a forward observer. A lightweight, portable close-air support radar to exercise this positive control is a critical component.

More difficult of resolution is insuring positive control over ground weapons. With infrared-homing missiles, such as Redeye, in the hands of the individual soldier, friendly aircraft become as vulnerable as the enemy's. There is no Identification, Friend or Foe (IFF) for weapons such as Redeye.

Hence a valid question has been raised as to whether the air defense missile is a usable weapon. Except under conditions of absolute air superiority (when Redeye wouldn't be needed anyway) the Air Force would be loath to have soldiers equipped with weapons which would be a threat to their aircraft.

It is likely that, as in past wars, there would be some sort of "guns tight" policy, under which, even if attacked, the ground forces are enjoined against firing at aircraft.

To make Redeye a usable weapon, the only answer is to assign aircraft corridors through which to fly. But this

is a major command and control problem which requires resolution.

Criticisms are leveled against the tactical doctrines covering the employment of armor, anti-tank weapons and close air support. Tanks, facing anti-tank weapons with kill probabilities approaching unity, cannot use familiar tactics. On the other hand, anti-tank weapons which rely on wire guidance to achieve these fantastic kill probabilities must at the same time evolve employment concepts to minimize the long times of flight involved.

Finally, the Redeye problem outlined earlier may be amenable to solution by a revision of tactical concepts for close air support.

GUIDANCE AND CONTROL

The US Army has launched a very broad effort to improve its missile guidance, not only in the inertial and electromagnetic areas but also for free rockets. The premise is that the cheapest guidance system is one that concentrates on aiming and eliminates flight hardware.

A new approach to free-rocket guidance is now being studied by theoretical mathematicians in an attempt to reduce a multitude of variables to a practical solution for field use.

Another major Army interest is a futuristic modular-type standardized missile capable of replacing at least Sergeant and Pershing and possibly Lance. A standard guidance module ring would be used with other functional stages added, depending on the type of performance needed.

The Army already has studied a single guidance system for Pershing and Sergeant. It found, however, that the Sergeant guidance problem is considerably more difficult, due primarily to atmospheric variables and influences.

Another way to simplify guidance systems is to perform more of the guidance functions with better propulsion control. The Lance approach is an example.

The Army is working intensely with strap-down inertial platforms — it will soon test three distinct methods in an attempt to find the best at the lowest cost. The two-

degree-of-freedom gyro appears to be gaining in popularity for pitch and yaw control.

New guidance techniques are called for in the anti-tank missile area. Ability to fire, then move immediately is much desired.

(Fluidic guidance and control systems also are being studied for the anti-tank roles and for a Missile-A type system of five miles range. A two-degree-of-freedom pneumatic gyro is under development, as are improved regulators and pickoffs.)

Supporting electronics for Army inertially guided missiles remains problematical. More standardization is needed between Pershing and Sergeant, particularly with the fire-control computer. Pershing support systems are being re-designed to reduce size, but the relative immobility of both systems is a complication. Missile set-up and alignment takes too long. The time to set up a launcher again after firing is considered far too long. (An interim measure already being employed is to provide operational missile units with more launchers per battery.)

SMALL CALIBER WEAPONS

One of the new trends in the development of small caliber weapons is the attempt to enhance the fire-power of conventional artillery with Rocket-Assisted Projectiles. The Rocket Assisted Projectile (RAP) now under development is intended to increase the stand off distance at which targets can be hit. In its present 5-in. version its ability to penetrate hardened point targets is questionable. The major development problem so far is RAP's erratic performance.

Another approach is a missile system — the Close-Support Assault Weapon. This would be a system with a range of at least 30 mi. Since it would be inertially guided until it reached the target area, one of the key questions is whether a low-cost, accurate inertial guidance system can be built.

Ultimate solution to the close support is likely to come from the Advanced Surface Missile System (ASMS). This system is presently planned to be capable of taking under fire surface as well as airborne targets.

A prime example of a missile system which will have to prove itself up and down the line is Lance, the division support weapon which is to replace the Honest John and possibly the Little John.

Primary problems with Lance to date have been with the restartable motor which, in turn, affects the accuracy since the guidance is tied to the precision performance of the engine. Accuracy is absolutely essential for Lance, which is to carry an advanced conventional warhead.

Even if Lance does achieve its circular error probable (CEP) requirements, there is still one major stumbling block to deployment. Can the troops in the field find targets for it? This problem of battle-field reconnaissance and surveillance is a general one. But the fact that it affects the deployment of Lance is in itself significant — and reflects a total approach that covers not only the performance of a weapon but its usability.

None of this is to say that Lance will not be deployed. In fact, in the context of replacement systems for Sergeant and Pershing, officials look on Lance as "kind of a replacement for Sergeant." Freely translated, this means that there is no specific system under consideration as a Sergeant replacement.

Pershing, however, is another story. With the range limitations on Army weapons "disappearing" a 700-mi. Pershing appears to be definitely under consideration. It is being termed a "product improvement" program, however, and officials talk in terms of a missile with improved propellants and grain designs as well as lightweight guidance. Although there has been no decision to develop such a weapon, there are programs in being to improve Pershing. Most immediate concern is to boost the readiness and reaction time of the long-range missile.

There is general dissatisfaction with the degree of ability to kill tanks at long ranges and with almost a unit probability. Key to the next generation of anti-tank weapons depends on guidance developments.

Shillelagh, which in general is felt to be a good weapon, has been criticized for its slowness — requiring the gunner to sit there exposed until the missile impacts. A supersonic version of the anti-tank missile is now under development. Also, an extended-range Shillelagh is to be

built. It is expected to travel many yards farther than the present model.

"It is claimed that a breakthrough in these weapons," has been made. The kill probability of Tow has been increased for first round hits. This is principally due to the optical sight to which is slaved a control system in the launcher, which in turn guides the missile by wire to the target.

In the light anti-tank category, the future is not at all clear. The M72, the present weapon filling this gap, is not really adequate for the job.

Requirements for missiles used in the direct fire role against a tank, are similar to those for ballistic missile defense. Specifically, high-burning-rate propellants are needed to get the missile to the target quickly. First, however, the structural and aerodynamic problems produced by these high velocities must be solved.

A laser illuminator used to guide a missile to its target is a promising approach, as is the optical contrast seeker for indirect fire. Both of these concepts demand more development, however, and both must overcome environmental limitations and high cost.

Section XI

TENDENCIES OF DEVELOPMENT: SPACE SYSTEMS

To complete the discussion the military aspects of the US space research need be brought up and reviewed. Of the numerous and varied ideas on the military use of space the one dealing with manned orbiting laboratory (MOL) appears to be of more immediate practical significance, though neither the specific military mission for such a laboratory nor the practical ways of its implementation have passed what is known as the "pre-program definition" stage. A very general outline of the military requirements for a manned space mission will include:

— ballistic missile early warning; the usefulness and effectiveness of a space-based system however, as well as its technical feasibility, potential complexity and cost are subject to serious question especially in the light of the possibilities of earth-based systems;

— in-space inspection, identification and classification of satellites; in this area again the practicability of application is just as obscure as the means by which these functions could be economically and effectively performed in space;

— support of existing or projected systems by performing such traditional military functions as navigation and weather observation. In these supporting roles space systems today do not offer a unique capability but rather a means of enhancing, augmenting and extending conventional capabilities.

MANNED ORBITING LABORATORY

The brief exposé provided above indicates that the MOL program will be directed specifically to fulfilling the need for an early effective determination of man's utility in performing military functions in space. This is a prerequisite to any definition of a mission and to specification of the design and performance parameters of an operational system needed to perform such a mission. Bioastronautics experiments are acquiring obvious importance, particularly human factor measurements, tolerance to weightlessness, effect of movement on attitude stability and man's ability to control re-entry after 30 days in orbit. The crew's ability to adjust, maintain and repair equipment as well as their general visual ability must also be evaluated.

Following is an enumeration of general parameters for MOL:

— a cylinder about 10 feet in diameter and 25 feet long weighing over 10,000 lbs.;

— double-walled to provide protection against meteorites, and divided into two pressurized compartments in case of meteorite penetration of one compartment;

— a third unpressurized compartment for vacuum component testing;

— a useful volume of 1,500 cubic feet and a useful payload, depending on the orbit of 4,000—5,000 lbs.

Two spacecraft for the MOL mission are at present under study by the US Air Force and the National Aeronautics and Space Administration (NASA): the Manned Orbiting Laboratory and the Manned Orbiting Research Laboratory (MORL). Below is a general definitions of the two programs.

Manned Orbiting Laboratory (MOL), US Air Force

Type: Two-man spacecraft
Status: Pre-program definition
Mission: To establish military usefulness of man in space
Configuration: Gemini-B capsule atop 10-ft.-dia., 20-ft.-long lab canister "about the size of a small house trailer"; lab weight estimated at 8,000 lbs. with total MOL weight of 18,000—20,000 lbs.; lab will be divided into three sections; a crew compartment, work area (both pressurized) and unpressurized area for experiments and equipment; capability of maintaining crew for 30 days in a shirt-sleeve environment
Orbit: Approximately 300-mi., orbit
Booster: Titan IIIC

Manned Orbiting Research Laboratory (MORL), NASA

Type: Manned space station
Mission: Carry four to six men on space station flights lasting up to one year
Configuration: Cylindrical structure with 5,000-cu.-ft. volume; weight, 30,000 lbs.
Status: Study
Contractor: Study contract, Douglas; many other system studies being made
Booster: Saturn IB

Gemini and Apollo

The MOL and MORL being in the pre-program stage two of the operational spacecraft — Gemini and Apollo — are being considered for modification to meet the requirements of the orbiting laboratories. These modified ver-

sions will serve as experimental stations to define both the missions and the parameters of MOL and MORL.

Gemini (NASA) is a two-man spacecraft capable of orbital flights lasting up to two weeks. It is 7 ft. high and weighs approximately 7,000 lbs.; launched by Titan II booster.

Apollo (NASA) is a 3-module spacecraft weighing 85,000 lbs; 12×13 feet in a "flattened cone" capsule shape. The command module weighs 10,000 lbs., accommodates a three-man astronaut crew and is intended to function an earth orbiter. (The two other module being service Module and Lunar Landing Vehicle). The earth orbiter is boosted by Saturn IB.

Gemini-X/Canister MOL System

A converted Gemini capsule (Gemini-X) associated with Titan IIIC booster is viewed as a probable MOL concept.

When adapted to the Titan IIIC booster and poised on the launch pad, the MOL vehicle will be about 153 ft. tall. From the top of Titan IIIC's Transtage, to the top of the Gemini-X capsule, the Gemini/canister payload will measure 54 ft. The canister design now measures 41 ft. long by 10 ft. in diameter.

About half this length will be used as a compartment with life-support systems providing a shirt-sleeve environment for MOL's two-man crew; the unpressurized remainder will be given over to instrumentation and power supply.

Entry to the canister section from the attached Gemini capsule in which the crew will ride into orbit will be provided through a hatch cut in the Gemini heat shield. Present concept calls for the two-man crew to remain in the shirt-sleeve environment of the laboratory section during the entire 30-day orbital period, keeping the capsule section in a standby condition, poised for the return to Earth at the end of a month in space, or earlier if necessary.

The pressurized life-support portion of the canister will have a capacity of 1,000 to 1,200 cu. ft. Although this area will accommodate limited instrumentation and its two-man crew, it will afford 400 cu. ft. of unencumbered

space for each man, as a working and living area. Total payload weight of the Gemini/canister package will be 25,000 lbs.

Two types of atmospheres are still under consideration for the pressurized canister section. One would be the basic nitrogen-oxygen combination found in the Earth's atmosphere and the other a helium-oxygen mixture.

Operating systems being adapted for MOL include packages for navigation, life support and power.

Re-entry from orbit will be accomplished by landings on water using the same techniques now in use for Gemini missions. However, MOL requirements will permit certain reductions in capsule weight, the Gemini-X version being adapted for the orbiting laboratory weighing approximately 6,000 lbs.

Experiments being prepared for MOL orbital flight will investigate all space phenomena that show promise of contributing to military needs. Major experiments involve tests of man's ability to make visual observations, conduct surveillance, investigate infrared phenomena, radio and radar signal propagation and background effects.

Extravehicular capabilities will be studied — particularly as they relate to man's ability to assemble structures such as radar antennas in space. Such structures might be as large as 100 ft. across, may be several times larger. Maintenance and repair functions will be studied in other assignments.

Intercept and identification functions are of major concern in the MOL program, with obvious military benefits.

MOL may be orbited at altitudes considerably higher than those recorded in Gemini flights to date because of the 30-day mission. Earlier indications from technical personnel have estimated that orbits may reach 350 n. mi.

Precise requirements for canister materials and construction haven't been revealed but its outer skin could be aluminum, presumably because present plans do not call for its re-entry or recovery.

Like the Gemini capsule, the MOL vehicle will have limited capability to alter its orbits.

Using the Titan IIIC Transtage (not a part of the final orbiting package), MOL can be inserted into orbits with a wide range of inclination.

Apollo MORL

As stated above plans are under consideration for the use of Apollo spacecraft as NASA Manned Orbiting Research Laboratory. The Apollo laboratory would use the Command and Service Module (C/—SM) and a laboratory that would replace the Lunar Excursion Module in the adapter area. The vehicle would be launched into 200-mi. Earth orbit by a Saturn IB and provide a module with 1,300 cu. ft. Apollo subsystems could supply the laboratory. It's lifetime would be about one year, with 30-day resupply. The basic module would weigh slightly more than 6,800 lbs.

The MORL would have a laboratory module with two independently pressurized compartments connected by an airlock.

In the larger compartment there would be — on decks or stories — a control deck from which laboratory operations and a major portion of the experiment program would be conducted, and an internal centrifuge for crew member therapy, physical condition testing, and re-entry simulation. Still below this level would be the flight crew quarters, including sleeping, eating, recreation, hygiene, and liquids laboratory facilities.

The smaller compartment would be a hangar/test area. Uses would include logistics maintenance, cargo transfer, experimentation, satellite checkout and flight crew habitation in case of emergency.

The nine-man vehicle could be launched unmanned into a low-inclination, near-Earth orbit by a Saturn IB. A ferry-resupply logistics system consisting of an Apollo Command Module, a cargo module and an S-IB stage would be launched immediately to bring the initial crew. Similar vehicles would be launched later for resupply.

The laboratory module and an Apollo Command Module could be launched with men on a two-stage Saturn V into high-inclination, near-Earth orbits. Manned launch also would be used for synchronous and lunar orbits, which also would require the Apollo Service Module and use of the three-stage Saturn V.

A laboratory with a volume of approximately 4,500 cu. ft. and 6 kw average power drain will be required for a

crew of nine, the MORL study said. The initial crew size recommended is six, and since extensive logistics support will be required, crew size should remain as small as practical until experience has been gained and operatonal logistics capability has evolved.

There would be two means of access to the MORL, one through the hangar/test area and one through the aft airlock. The hangar/test area, separated from the forward pressure compartment by an inverse-pressure bulkhead, would act as a transfer airlock for personnel moving from the logistics spacecraft into the main portion of the laboratory.

VEHICLES

The heavy payloads quite obviously put heavy demands on the vehicles. Of the existing family of spaceboosters the following are being considered for the job.

Saturn I (NASA)

Type: Two-stage space launch vehicle with 1.5-million-lbs. thrust booster

Mission: Boost boilerplate Apollo spacecraft in Earth-orbital flights

Status: R&D

Frame: 21.6 ft. wide; 125 ft. high

Configuration: SI stage, eight HI engines developing 1.5 million lbs. thrust; SIV stage, six RL-10-A3 engines with 90,000 lbs. thrust

Propulsion: All liquid; LOX/RP, A-3 LOX/H_2

Payload: 15,000 lbs. in 345-mi. orbit

Saturn IB (NASA)

Type: Two-stage space vehicle with 1.5 million lbs. thrust in the booster

Mission: Boost Apollo spacecraft (including lunar-landing vehicle) models in Earth-orbital flights; also may be used as a supply vehicle in future programs

Status: R&D

Frame: 21.6 ft. dia., 141 ft. high

Configuration: SIB stage, eight HI engines, total thrust 1.5 million lbs., first-stage thrust now being increased to 1.6 million lbs.; S-IVB stage, one J-2 engine, 200,000 lbs. thrust

Propulsion: All liquid; LOX/RP; LOX/H_2

Payload: 28,500 lbs. in 345-mi. Earth orbit

Titan II (NASA)

Type: Manned space booster

Status: Development

Prime Contractor: Martin

Configuration: Essentially same as Titan II missile, with addition of redundant electrical power and flight control systems, a malfunction detection system to warn of abort situations and a radio command guidance system such as that used in Mercury

Titan III (Air Force)

Military Designation: Program 624A

Type: Standard space booster for quick-reaction military missions

Status: Development

Performance: Capable of placing 5,000—25,000 lbs. in low Earth orbits or 2,100 lbs. in synchronous orbits, depending on configuration

Propulsion: Core vehicle — two liquid rocket engines with 430,000 lbs. thrust total; one liquid rocket engine with 100,000 lbs. thrust, and two liquid rocket engines with 8,000 lbs. thrust each; "outboard motors" of two solid rockets, each 120-in. dia. generating over 2,000,000 lbs. thrust total and weighing 500,000 lbs. each

Configuration: Titan IIIA is core vehicle (modified Titan II) with third (trans) stage; Titan IIIC is full vehicle, using both outboard solid rockets; configuration used depends on mission parameters

Titan III-Transtage

Manufacturer: Aerojet-General

Propellants: Storables — nitrogen tetroxide, Aerozene-50

Start System: Gas pressurized system

Ignition: Hypergolic

Thrust: 16,000 lbs. total — 8,000 lbs. from each of the twin barrels

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PART II

NUCLEAR WEAPONS AND ATOMIC DEFENSE

Part II discusses the basic facts of the atomic theory, the nuclear fission and fusion reactions, the mechanism of the nuclear weapons, the nuclear explosion phenomena, the effects of nuclear explosion on personnel and materiel and the methods of atomic (nuclear) defense accepted in the US Army.

Section I

ATOMIC THEORY. BASIC PHYSICS AND PRINCIPLES OF THE NUCLEAR DEVICE

ATOMIC STRUCTURE AND ISOTOPES

All substances are made up from one or more of about ninety different kinds of simple materials known as "elements." Among the common elements are the gases (e. g. hydrogen, oxygen), the solid nonmetals (e. g. carbon, sulfur), and various metals (e. g. iron, copper), a less familiar element, which has attained prominence in recent years because of its use as a source of atomic (or nuclear) energy, is uranium, normally a solid metal.

The smallest part of any element that can exist, while still retaining the characteristics of the element, is called an "atom" of that element. Thus, there are atoms of hydrogen, of iron, of uranium, etc. The hydrogen atom is the lightest of all atoms, whereas the atoms of uranium are the heaviest of those found in nature.

Every atom consists of a relatively heavy central re-

gion or "nucleus," surrounded by a number of very light particles known as "electrons."

The electrons are negatively charged and revolve around nucleus in the orbits. The number of electrons and their arrangements are characteristic for the element concerned (Fig. 17). The nucleus consists of a closely packed globular assembly of elementary particles referred to as protons and neutrons.

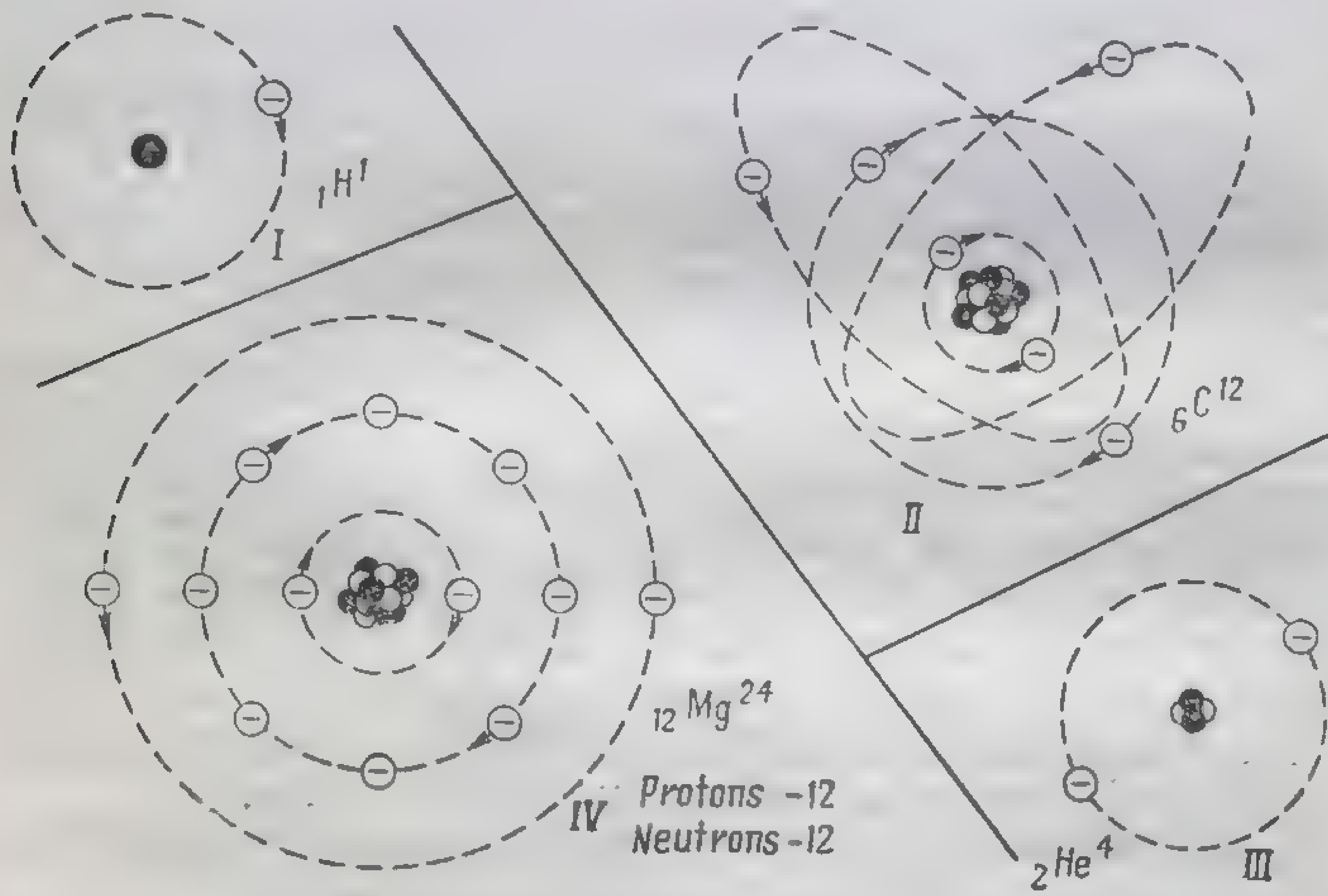

Fig. 17. Diagrammatic representation of atoms.

These two particles have almost the same mass, but they differ in the respect that the proton carries a unit charge of positive electricity whereas the neutron, as its name implies, is uncharged electrically, i. e., it is neutral. Because of the protons present in the nucleus, the latter has a positive electrical charge, but in the normal atom this is exactly balanced by the negative charge carried by the electrons surrounding the nucleus.

The essential difference between atoms of different elements lies in the number of protons (or positive charges) in the nucleus; this is called the "atomic number" of the element. Hydrogen atoms, for example, contain only one proton, and plutonium atoms 94 protons. Although all the nuclei of a given element contain the same number of

protons, they may have different numbers of neutrons. The resulting atomic species, which have identical atomic numbers but which differ in their masses, are called "isotopes" of the particular element. All but about 20 of the elements occur in nature in two or more isotopic forms, and many other isotopes, which are unstable, i. e., radioactive, have been obtained in various ways.

RADIOACTIVITY AND NUCLEAR FISSION

Radioactivity is a process by which the unstable atom achieves stability. The process is accomplished by the emission of nuclear particles, of which alpha and beta are examples, and of gamma rays. A gamma ray is similar to a high energy X-ray.

Two types of radioactivity is being discerned: natural and artificial. Natural radioactivity is a spontaneous transmutation by which an element reduces its atomic weight and converts itself into a new and more stable element lower in the periodic table. The process cannot be modified by the application of heat, cold, pressure or any chemical reagent. It goes on at a rate characteristic for the element concerned and follows a pattern typical for what is termed a radioactive decay series.

Artificial radioactivity does not differ essentially from natural radioactivity save that it is produced in elements by man-made means, i. e., by the bombardment of an element by any of several nuclear particles.

Fission is a process by which an atomic nucleus splits into two fragments after it has been penetrated by an incident particle of sufficient energy.

Fission can be produced by neutrons, protons, deuterons, alpha particles and energetic gamma rays. Of these agents, the neutron is the most effective because of its ability to pass easily into a nucleus by reason of its neutral electric charge.

A considerable number of elements display the fission reaction toward bombardment with particles of high energy.

Whereas a number of elements display the fission reaction under neutron bombardment, it is necessary that fission of a nucleus be attended by the simultaneous emission of extra neutrons if a chain reaction is to be

established. In common practice, therefore, fissionability refers rather specifically to uranium-233, uranium-235 and plutonium-239. These elements are able to carry on a selfsustained chain reaction and will, furthermore, be fissioned by either low- or high-energy neutrons.

The mechanism of fission can be compared to the splitting of a fluid drop or mitosis in a living cell. A neutron enters the nucleus of uranium-235 and converts it to the greatly excited uranium-236. The spherical configuration of this nucleus is altered; the protons, because

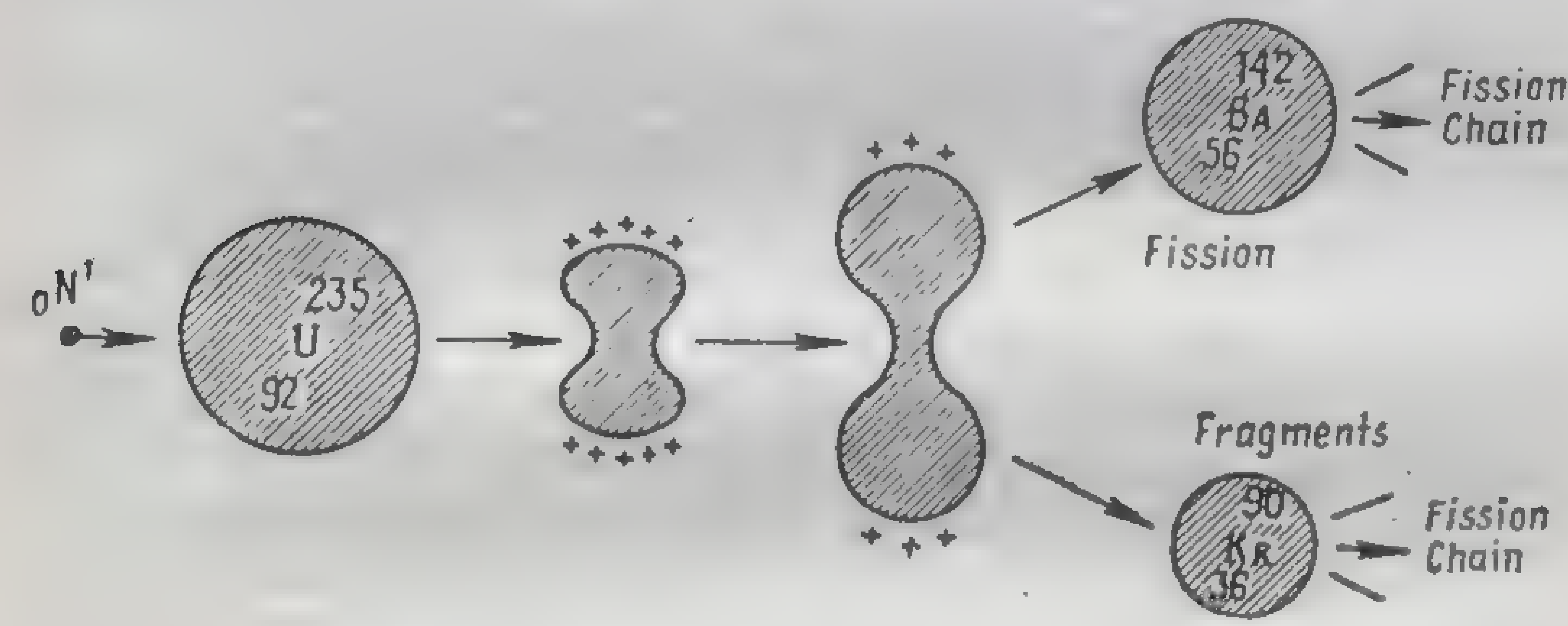

Fig. 18. Fission of U-235 nucleus.

of electric repulsion, tend to distort further the now elongated structure (Fig. 18). An indentation occurs and the nuclear forces are no longer able to contain the natural repellent forces of the protons. The indentation deepens and complete fracture occurs. This entire reaction takes place in an average of 10^{-12} second.

The two fission fragments move away from each other with great velocity.

FISSION PRODUCTS

Many different fission fragments, i. e., initial fission product nuclei, are formed when uranium (or plutonium) nuclei capture neutrons and suffer fission. This is because there are 40 or so different ways in which the nuclei can split up when fission occurs. Most, if not all, of the approximately 80 fragments thus produced are the nuclei of radioactive forms (radioisotopes) of well-known, lighter elements. The radioactivity is usually manifested by the

emission of negatively charged beta particles. This is frequently, although not always, accompanied by gamma radiation, which serves to carry off excess energy. In a few special cases, gamma radiation only is emitted.

The rate of radioactive change, i. e., the rate of emission of beta particles and gamma radiation, is usually expressed by means of the "half-life" of the particular isotope involved. This is defined as the time required for the radioactivity of a given quantity of a particular radioisotope of decrease (or decay) to half of its original value. Each individual radioactive species has a definite half-life which is independent of its state or its amount. The half-lives of the fission products have been found to range from a small fraction of a second to something like a million years.

In addition to the beta-particle and gamma-ray activity due to the fission products, there is another kind of residual radioactivity that should be mentioned. Both uranium and plutonium are radioactive, and their activity consists in the emission of what are called "alpha particles." These are a form of nuclear radiation, since they are emitted from atomic nuclei; but they differ from the beta particles arising from the fission products in being much heavier and carrying a positive electrical charge. Alpha particles are, in fact, identical with the nuclei of helium atoms.

Because of their greater mass and charge, alpha particles are much less penetrating than beta particles and gamma rays of the same energy. Thus, very few alpha particles from radioactive sources can travel more than 1 to 3 inches in air before being stopped. It is doubtful whether these particles can get through the unbroken skin, and they certainly cannot penetrate clothing. If plutonium enters the body in sufficient quantity, by ingestion, inhalation, or through skin abrasions, the effects may be serious.

MASS DEFECT AND ENERGY RELEASED IN FISSION

Fission of the uranium nucleus releases energy to the external world by reason of the fact that the total mass of the split products is less than the mass of the original

uranium. The mass lost is converted to energy. This is an application of the Einstein equation:

$$E = mc^2$$

Einstein's theory holds that mass and energy are different forms of the same thing. Neither can be destroyed. Under proper conditions either is converted to the other. Such an approach is necessary if an answer is sought to the question of why such astonishing yields of energy come from relatively small amounts of matter in an atomic bomb.

The Einstein formula, $E = mc^2$, expresses the equivalence of mass and energy. In the formula E is energy, m — the mass apparently lost in a reaction and c — the velocity of light in centimeters per second (30 billion cm/sec.).

The apparent loss in a physical reaction can be illustrated by an example. The uranium-235 nucleus contains 92 protons and 143 neutrons. If the mass of a proton is 1.00758 and that of a neutron 1.00896, then the calculated mass of the uranium nucleus should be

$$\begin{array}{rl} 92 \times 1.00758 = & 92.69736 \\ 143 \times 1.00896 = & \underline{144.28128} \\ & 236.97864 \text{ mass units} \end{array}$$

But the actual isotopic weight of the uranium-235 nucleus is 235.124. Subtraction of the actual from the calculated mass shows that there has been an apparent loss of 1.85464 mass units when the nucleons were brought together.

It will be seen that this mass, though apparently lost, has not been lost at all. It has been converted to energy. One unit of mass, when converted to energy, yields 931 Mev. The conversion of 1.85464 units therefore yields 1,726.67 Mev. The latter figure is designated as the binding energy of the uranium-235 nucleus.

These terms can now be defined. Mass defect is the difference between the calculated mass of a nucleus, determined from the sum of the masses of the individual nucleons, and its actual mass, shown by instrumental methods. When this apparent loss of mass is converted, it is termed the binding energy. Binding energy does not

remain in the nucleus; it is released when the nucleus is formed by its constituent protons and neutrons. It can be thought of as the energy required to force the nucleons into the packed nucleus. It is the energy that holds the nucleons together in the nucleus. This same amount of energy will be required to disintegrate nucleus.

Binding energy per nucleon is obtained by dividing the total binding energy of a nucleus by the number of its nucleons. In the case of uranium-235 this is 7.35 Mev per nucleon. Above the level of boron-10, all binding energies per nucleon are in the order of 7 or 8 Mev.

In comparative equivalents, and assuming that the efficiency of fission is 100 per cent, 1 lb. of uranium-235 yields the energy of 10,000 tons and 2 lbs. the energy of 20,000 tons of TNT.

FISSION CHAIN REACTION AND CRITICAL MASS. THE ATOMIC DEVICE

The significant point about the fission of a uranium (or plutonium) nucleus by means of a neutron, in addition to the release of a large quantity of energy, is that the process is accompanied by the almost instantaneous emission of two or more other neutrons. The neutrons liberated in this manner are able to induce fission of additional uranium (or plutonium) nuclei, each such process resulting in the emission of more neutrons which can produce further fission, and so on. Thus, in principle, a single neutron could start off a chain of nuclear fissions, the number of nuclei involved, and the energy liberated, increasing at a tremendous rate.

Actually, not all the neutrons liberated in the fission process are available for causing more fissions; some of these neutrons escape and others are lost in nonfission reactions. It will be assumed, however, for simplicity, that for each uranium (or plutonium) nucleus undergoing fission, there are two neutrons produced capable of initiating further fissions. Suppose a single neutron is captured by a nucleus in a quantity of uranium, so that fission occurs. Two neutrons are then liberated and these cause two more

nuclei to undergo fission. This results in the production of four neutrons available for fission, and so on.

Accordingly, the number of neutrons, and hence, the number of nuclei undergoing fission, is doubled in each generation. Starting with a single neutron the number would increase rapidly, thus, 1, 2, 4, 8, 16, 32, 64, ... In less than 90 generations enough neutrons would have been produced to cause the fission of every nucleus in 50 kilograms (110 pounds) of uranium, resulting in the liberation of the same amount of energy as in the explosion of a million tons (1 megaton) of TNT.

The time required for the actual fission process is very short, and most of the resulting neutrons are emitted promptly. Consequently, the interval between successive generations is determined by the average time elapsing between the release of the neutron and its capture by a fissionable nucleus. This time depends, among other things, on the energy (or speed) of the neutron, and if most of the neutrons are of fairly high energy, generally referred to as "fast neutrons," the interval is about a one-hundred-millionth part of a second. In this event, the 90th generation would be attained in less than a millionth of a second. The release of the energy, equivalent of 1 megaton of TNT in such a short time would provide the conditions for a tremendous explosion.

It is seen, therefore, that because the fission process is accompanied by the instantaneous liberation of neutrons, as well as by the release of energy, it is possible, in principle, to produce a self-sustaining, chain reaction. As a result, a few pounds of fissionable material can be made to liberate, within a very small fraction of a second, as much energy as the explosion of thousands (or millions) of tons of TNT. This is the basic principle of the nuclear fission bomb.

It was mentioned above that some of the neutrons produced in fission are lost by escape or by capture in nonfission processes. If the conditions are such that the neutrons are lost at a faster rate than they are formed by fission, the chain reaction would not be self-sustaining. Some energy would be produced, but the amount would not be large enough, and the rate of liberation would not be sufficiently fast, to cause an effective explosion. It is necessary, therefore, in order to achieve a nuclear explo-

sion, to establish conditions under which the loss of neutrons is minimized. In this connection, it is important to consider, in particular, the neutrons which escape from the material undergoing fission.

The escape of neutrons occurs at the exterior of the uranium (or plutonium) mass. The rate of loss by escape will thus be proportional to the surface area. On the other hand, the fission process, which results in the formation of more neutrons, takes place throughout the whole of the material and its rate is, consequently, dependent upon the volume. The relative loss of neutrons by escape can, therefore, be reduced by increasing the size of the fissionable material, for in this manner the ratio of the area to the volume is decreased.

If the quantity of uranium (or plutonium) is small, i. e., if the ratio of the surface area to the volume is large, the proportion of neutrons lost by escape will be so great that the propagation of a nuclear fission chain, and hence the production of an explosion, will not be possible. But as the size of the piece of uranium (or plutonium) is increased, and the relative loss of neutrons is thereby decreased, a point is reached at which the chain reaction can become self-sustaining. This is referred to as the "critical mass" of the fissionable material.

For a nuclear explosion to take place, the weapon must thus contain a sufficient amount of uranium (or plutonium) for it to exceed the critical mass in the existing circumstances. Actually, the critical mass depends, among other things, on the shape of the material, the composition, and the presence of impurities which can remove neutrons in nonfission reactions. By surrounding the fissionable material with a suitable neutron "reflector," the loss of neutrons by escape can be reduced and the critical mass can thus be decreased.

Because of the presence of stray neutrons in the atmosphere or the possibility of their being generated in various ways, a quantity of a suitable isotope of uranium (or plutonium) exceeding the critical mass would be likely to melt or possibly explode. It is necessary, therefore, that before the detonation of a nuclear bomb, it should contain no piece of fissionable material that is a large as the critical mass for the given conditions. In order to produce an explosion, the material must then be

made supercritical, i. e., larger than the critical mass, in a time so short as to preclude a subexplosive change in the configuration, such as by melting.

ATTAINMENT OF SUPERCRITICAL MASS. THE PRINCIPLE OF THE NUCLEAR FISSION DEVICE. "FAT MAN", "LITTLE BOY"

Two general methods have been described for bringing about a nuclear explosion, that is to say, for quickly converting a subcritical system into a supercritical one. In the first method, two or more pieces of fissionable material, each less than a critical mass, are brought together very rapidly in order to form one piece that exceeds the critical mass. This may be achieved in some kind of gun-barrel device, in which a high explosive is used to blow one subcritical piece of fissionable material from the breech end of the gun into another subcritical piece firmly held in the muzzle end.

This method was used in the first nuclear bomb. The bomb known as the "Little Boy" was detonated over Hiroshima in Japan.

The second method makes use of the fact that when a subcritical quantity of an appropriate isotope of uranium (or plutonium) is strongly compressed, it can become critical or supercritical. The reason for this is that by decreasing the size and, hence, the surface area (or neutron escape area) of a given quantity of fissionable material by compression, the rate of neutron loss by escape is decreased relative to the rate of production by fission. A self-sustaining chain reaction may then become possible with the same mass that was subcritical in the uncompressed state.

The compression may be achieved by means of a spherical arrangement of specially fabricated shapes of ordinary high explosive. In a hole in the center of this system is placed a subcritical sphere of fissionable material. When the high explosive is set off, by means of a number of detonators on the outside, an inwardly-directed "implosion" wave is produced. When this wave reaches the sphere of uranium (or plutonium), it causes the latter to be compressed so that it becomes supercritical and explodes.

The implosion method was used in another type of atomic bomb developed during World War II. The bomb was called the "Fat Man" and was detonated in Japan over Nagasaki.

Following are the main characteristics of the "Fat Man" and the "Little Boy."

"Little Boy" (Fig. 19) being 10 feet long and weighing 9,000 pounds is the simpler of the two A-bombs, this device was dropped from a B-29 bomber. The plugs at the

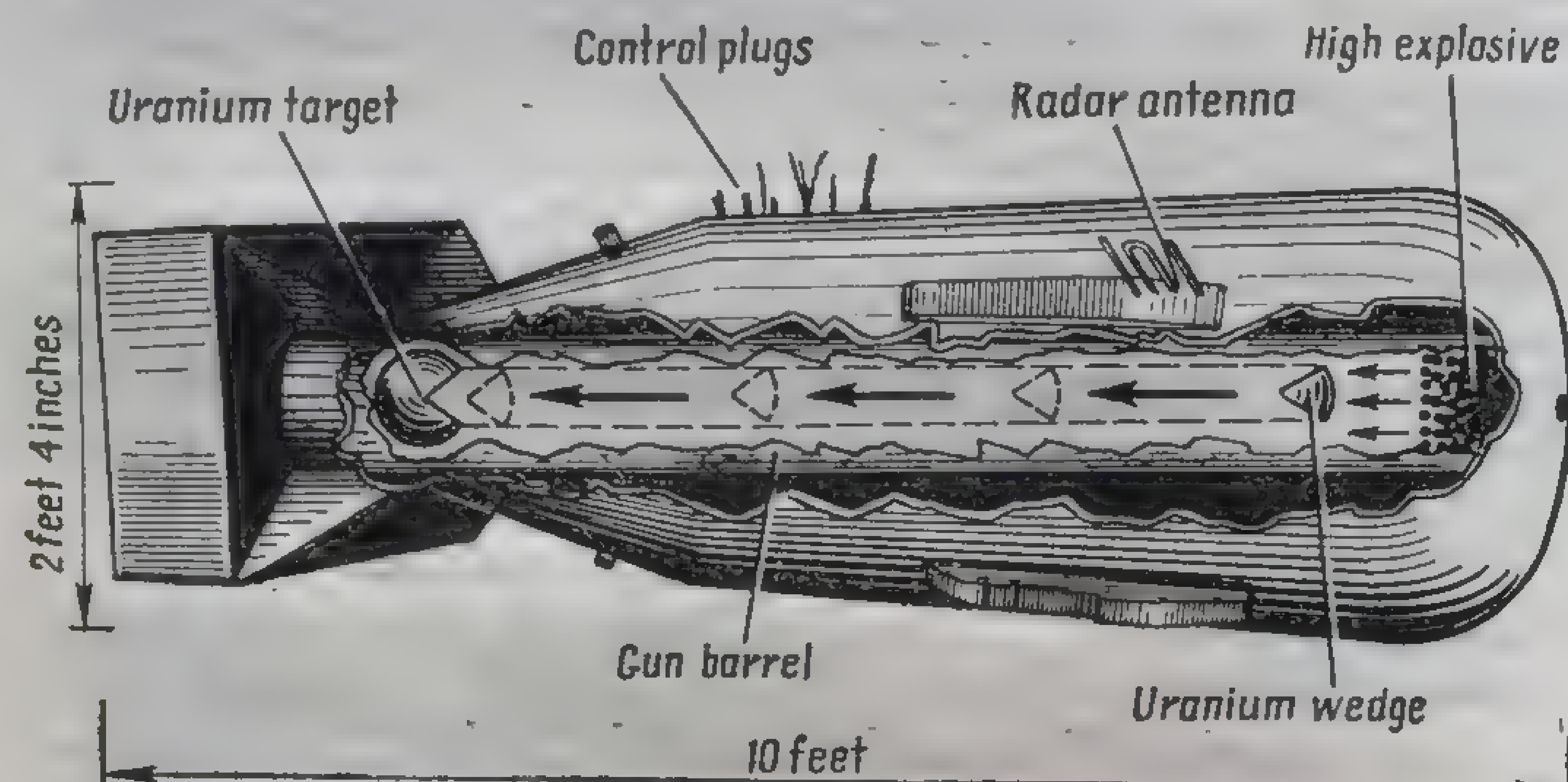

Fig. 19. Principal drawing of the "Little Boy" nuclear device.

top provide "ready" and "armed" control for the bombardier while the device is still suspended in the bomb bay. The TV-like antenna on the side is part of a radar proximity fuse. At 1,850 feet, radar echo from the ground triggers a conventional explosive. Nuclear triggering itself takes place in a gun-barrel tube. A small wedge of uranium-235 is driven down the barrel by the chemical explosion into a larger chunk of U-235, the mass becomes overcritical, fissions and explodes with the force of 20,000 tons of TNT.

"Fat Man" (Fig. 20), 10 feet 8 inches long and weighing 10,000 pounds is a plutonium bomb. The bay controls and the proximity fuse are similar to those on the "Little Boy." Its nuclear mechanism, however, uses the implosion principle. A small beryllium core provides a core of fission-sustaining neutrons. Around it is a hol-

low plutonium sphere about the size of a baseball. Surrounding this arrangement is a solid sphere made up of 36 finely machined prisms of high explosive. When detonated, the high explosive simultaneously converges or implodes on the plutonium, crunching it into an overcritical mass.

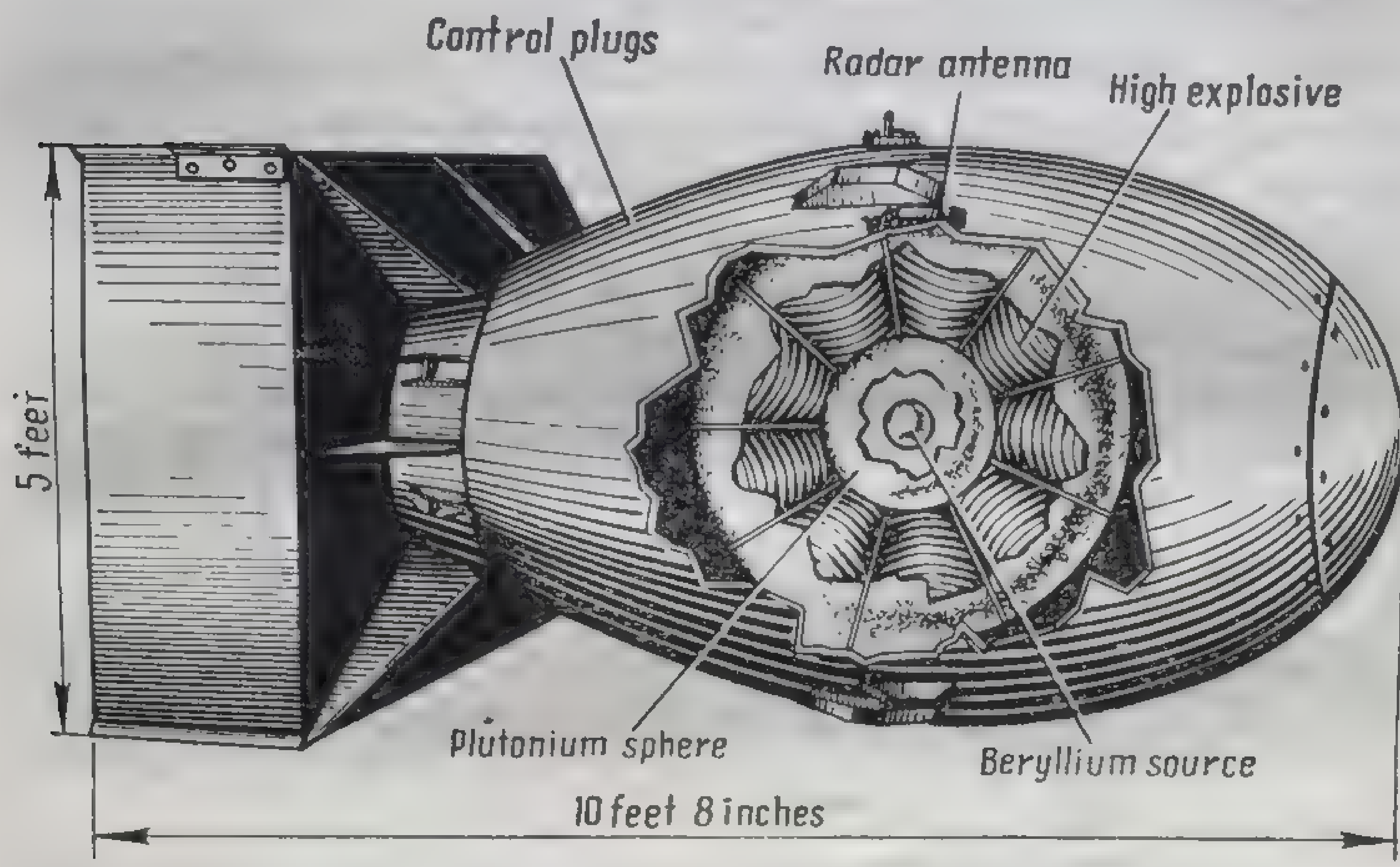

Fig. 20. Principal drawing of the "Fat Man" nuclear device.

FUSION REACTION AND THE PRINCIPLES OF THE HYDROGEN 3F BOMB

We have so far reviewed the process of the release of the energy within the atom's nucleus by nuclear fission. Nuclear energy however can be also released by what is known as the process of fusion. In nuclear fusion, a pair of light nuclei unite (or fuse) together, to form a nucleus of a heavier atom.

Energy production in the sun and stars is undoubtedly due to fusion reactions involving the nuclei of various light (low atomic weight) atoms. From experiments made in laboratories with cyclotrons and similar devices, it was concluded that the fusion of isotopes of hydrogen was possible. This element is known to exist in three isotopic forms, in which the nuclei have masses of 1, 2 and 3, respectively. These are generally referred to as hydrogen (H^1), deuterium (H^2 or D^2), and tritium (H^3 or T^3). All

the nuclei carry a single positive charge, i. e., they all contain one proton, but they differ in the number of neutrons. The lightest (H^1) nuclei (or protons) contain no neutrons; the deuterium (H^2) nuclei contain one neutron, and tritium (H^3) nuclei contain two neutrons.

Nuclear fusion reactions can be brought about by means of very high temperatures, and they are thus referred to as "thermonuclear processes." The actual quantity of energy liberated, for a given mass of material, depends on the particular isotope (or isotopes) involved in the nuclear fusion reaction. As an example, the fusion of all the nuclei present in 1 pound of the hydrogen isotope deuterium would release roughly the same amount of energy as the explosion of 26,000 tons of TNT.

Four thermonuclear fusion reactions appear to be of interest for the production of energy because they are expected to occur sufficiently rapidly at realizable temperatures.

These are:

$$H^2 + H^2 = He^3 + n + 3.2 \text{ Mev}$$
$$H^2 + H^2 = H^3 + H^1 + 4 \text{ Mev}$$
$$H^3 + H^2 = He^4 + n + 17.6 \text{ Mev}$$
$$H^3 + H^3 = He^4 + 2n + 11.3 \text{ Mev},$$

where He is the symbol for helium and n (mass = 1) represents a neutron. The energy liberated in each case is expressed in Mev (million electron volt) units. Without going into details, it may be stated that the fission of a nucleus of uranium or plutonium, having a weight of nearly 240 atomic mass units, releases about 200 Mev. This may be compared with an average of about 24.2 Mev obtained from the fusion of 4 deuterium nuclei with a weight of 10 mass units. Weight for weight, therefore, the fusion of deuterium nuclei would produce nearly three times as much energy as the fission of uranium or plutonium.

In order to make the nuclear fusion reactions take place, temperatures of the order of a million degrees are necessary. The only known way in which such temperatures can be obtained on earth is by means of a fission explosion. Consequently, by combining a quantity of deuterium or tritium (or a mixture) with a fission bomb, it

should be possible to initiate one or more of the thermonuclear fusion reactions given above. If these reactions, accompanied by energy evolution, can be propagated rapidly through a volume of the hydrogen isotope (or isotopes) a thermonuclear explosion may be realized.

It may be noted that the two reactions involving tritium (H^3) are of particular interest for several reasons. Not only do they occur more rapidly than those in which deuterium alone takes part and produce more energy, but in addition one or two neutrons are emitted in each case.

These can cause fission in uranium and plutonium. Consequently, association of the appropriate fusion reactions with a fissionable material will result in a more complete utilization of the latter for the release of energy. A device in which fission and fusion (thermonuclear) reactions are combined can therefore produce an explosion of great power.

This principle is made use of in the so-called 3F bomb — the fission-fusion-fission device (Fig. 21). The 3F bomb has fission trigger which causes fusion; the fusion in turn acts as a booster to give the bomb its big punch which comes from the final fissioning of the bomb's uranium-238 casing.

The uranium-238 casing of the 3F bomb encloses lithium hydride (Li^6H^2 and Li^6H^3) — a compound containing hydrogen for fusion. Evenly spaced around lithium hydride are spheres of plutonium powder. Each is plastered with many electrically triggered implosion charges to set off bomb. Each has core of beryllium and polonium which produce neutrons to help start fission. Since polonium loses its radioactivity, fresh cores are inserted through casing at end of rods shortly before bomb drop.

The explosion sequence of the 3F device comprises three stages (Fig. 22).

The first stage is the implosion of plutonium into supercritical masses by means of the simultaneous explosion of the HE charges. Once the supercritical masses are attained fission begins.

The second stage is that of fusion. Heat from fission is held in by the casing and focused on lithium hydride to cause fusion of many hydrogen nuclei into helium:

$$Li^6 + H^2 \rightarrow He^4$$

Nuclei of lithium when bombarded by neutrons produce additional quantities of H^3; then follows the reaction which has already been described:

$$H^3 + H^2 \rightarrow He^4 + n + 17.6 \text{ Mev}$$

The third stage is fission. The neutron released in the fusion reaction causes the fission of the U-238 casing.

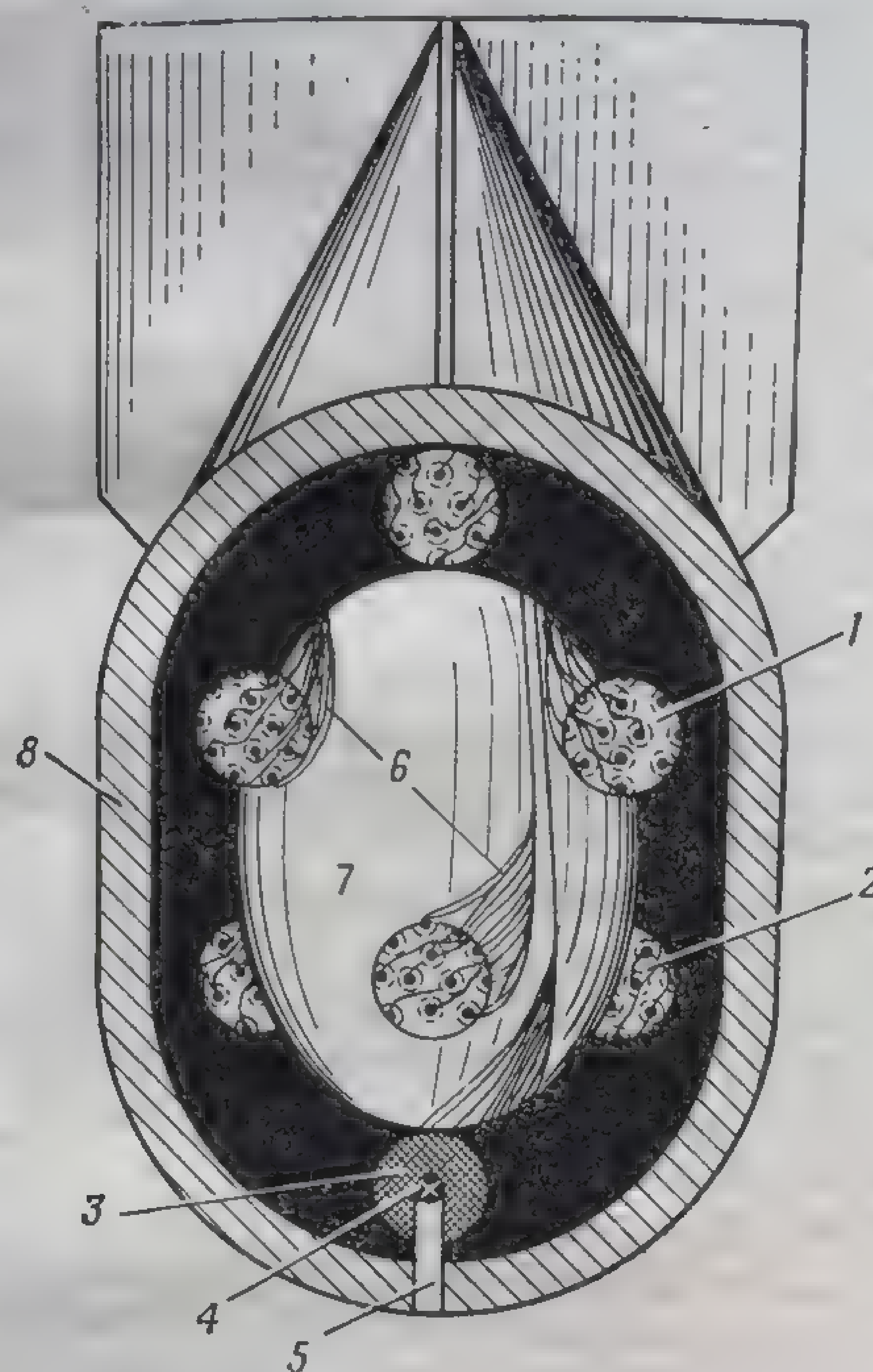

Fig. 21. Principal design of the thermonuclear bomb:

1 and *2* — plutonium implosion charges; *3* — cutaway of plutonium charge; *4* — beryllium-polonium core; *5* — rod for inserting core; *6* — wiring from implosion charges to switch box; *7* — lithium hydride; *8* — U-238 casing.

The U-238 is the plentiful form of the metal which yields minute quantities of its dangerous U-235. Ordinarily U-238 resists fissioning. But when it is struck by the intense hail of fast neutrons released by the fusion

even U-238's tough atoms give way and fission with a force equivalent to 10 to 20 mln tons of TNT (each fission yielding 10 times as much energy as fusion).

This three stage sequence lasts millionths of a second.

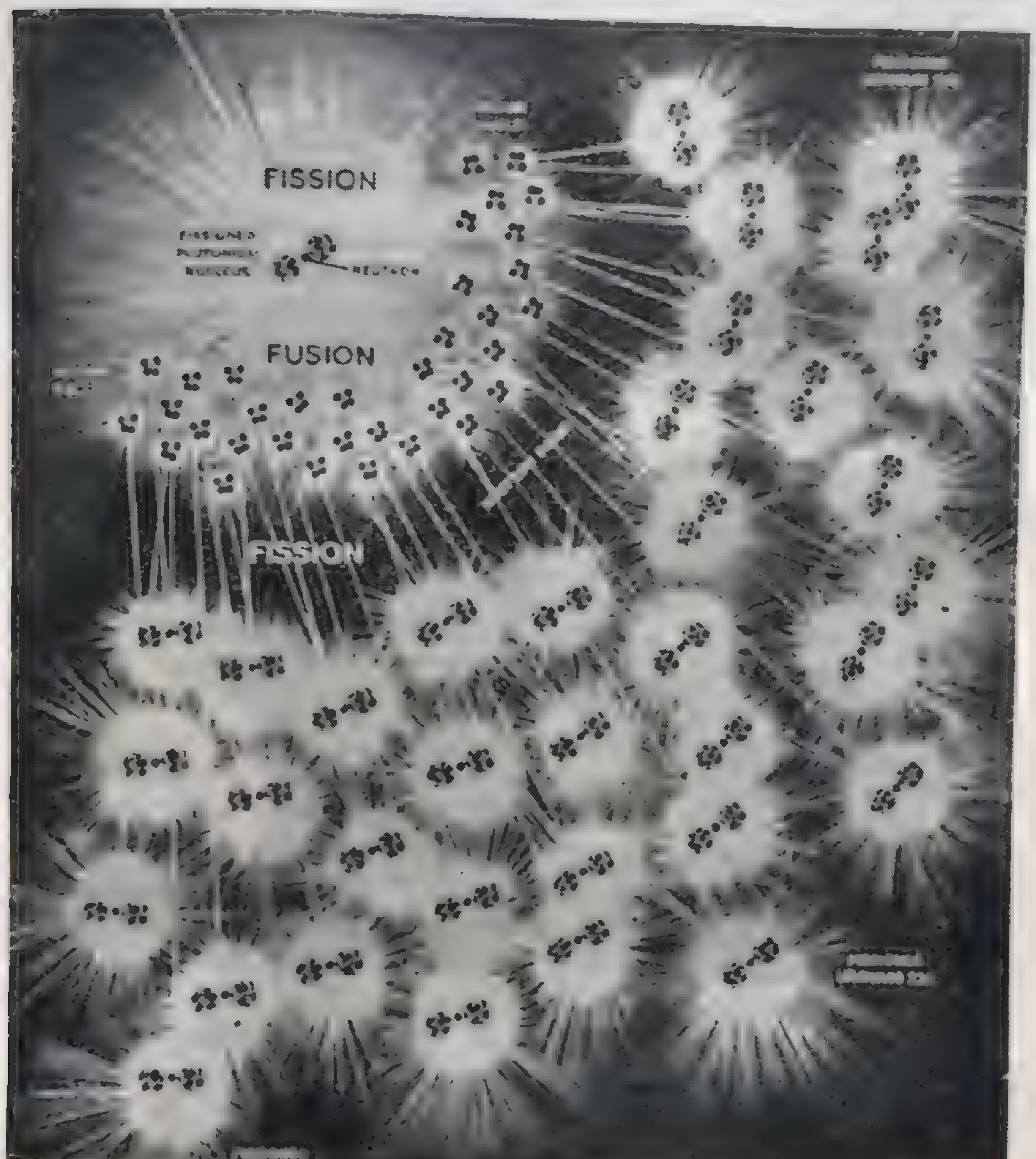

Fig. 22. Three stages of the explosion sequence.

THE COBALT AND THE SODIUM BOMBS

It is possible to encase a hydrogen-uranium bomb in a capsule built of elements capable of capturing free neutrons. Having captured the neutrons these elements

will become radioactive isotopes, and emit gamma rays and beta particles thus contaminating the ground (atmosphere).

The choice of the elements for the capsule will depend on the desired length of contamination.

Cobalt-59, a stable isotope, will, by capturing one neutron, become radioactive cobalt-60 — a beta and gamma emitter with a half-life of 5.3 years. Such a contamination in the atmosphere would produce a long-continued radioactive hazard.

A more damaging bomb would have a blanket of sodium oxide. By absorbing neutrons sodium-23 becomes radioactive sodium-24 with rate of emission 100—500 times higher than that of the cobalt bomb with a blanket of the same weight and corresponding hydrogen-uranium charge but with the half-life of 15 hours only. It has been calculated that the sodium contaminated area will within six months be completely clear of the fallout.

Section II

NUCLEAR EXPLOSION PHENOMENA

In general, an explosion is the release of a large amount of energy in a short interval of time within a limited space. The liberation of this energy is accompanied by a considerable increase of temperature, so that the products of the explosion become extremely hot gases. These gases, at very high temperature and pressure, move outward rapidly. In doing so, they push away the surrounding medium — air, water, or earth — with great force, thus causing the destructive (blast or shock) effects of the explosion. The term "blast" is generally used for the effect in air, because it resembles (and is accompanied by) a very strong wind. In water or under the ground, however, the effect is referred to as "shock", because it is like a sudden impact.

The atomic (or nuclear) [1] bomb is similar to the more conventional (or high explosive) type of bomb in so far as its destructive action is due mainly to blast or shock.

[1] The terms "atomic" and "nuclear" may be used interchangeably as far as weapons or explosions are concerned.

However, apart from the fact that nuclear bombs can be many thousands of times more powerful than the largest TNT bombs, there are other more basic differences. First, a fairly large proportion of the energy in a nuclear explosion is emitted in the form of light and heat, generally referred to as "thermal radiation." This is capable of causing skin burns and of starting fires at considerable distances. Second, the explosion is accompanied by highly-penetrating and harmful, but invisible, rays, called the "initial nuclear radiation." Finally, the substances remaining after a nuclear explosion are radioactive, emitting similar radiations over an extended period of time. This is known as the "residual nuclear radiation" or "residual radioactivity."

It is because of these fundamental differences between a nuclear and a conventional (TNT) explosion, as well as because of the tremendously greater power of the former, that the effects of nuclear weapons require special consideration. In this connection, a knowledge and understanding of the mechanical and radiation phenomena associated with a nuclear explosion are of vital importance.

DISTRIBUTION OF ENERGY IN NUCLEAR EXPLOSIONS

In the explosion of a conventional (TNT) bomb nearly all the energy released appears immediately as kinetic (or heat) energy. Almost the whole of this is then converted into blast and shock. In a fission weapon, however, the situation is different. Only about 85 per cent of the energy released in fission is in the form of heat (kinetic) energy, and only a part of this is utilized to produce blast and shock. The other part of this 85 per cent appears as thermal radiation, i. e., heat and light rays. This is a result of the very much higher temperature attained in a nuclear, as compared with a conventional, explosion. The fraction of the fission energy emitted as thermal radiation varies with the nature of the weapon and with the conditions of the explosion, but for a bomb burst fairly high in the air it is roughly one-third. Consequently, about 50 per cent of the total energy is then utilized to cause blast and shock.

The remaining 15 per cent of the energy of the nuclear explosion is released as various nuclear radiations. Of this, 5 per cent constitute the initial nuclear radiations produced within a minute or so of the explosion; whereas the final 10 per cent of the bomb energy is emitted over a period of time in the form of the residual nuclear radiation. This is due almost entirely to the radioactivity of the fission products present in the bomb residue after the explosion. It may be noted that in a conventional explosion, there are no nuclear radiations since the atomic nuclei are unaffected.

The initial nuclear radiations consist mainly of gamma rays (resembling X-rays) and neutrons. Both of these, especially the gamma rays, can travel great distances through the air and can even penetrate considerable thicknesses of material. It is because these radiations can neither be seen nor felt by human beings, but can have harmful effects even at a distance from their source, that they are an important aspect of a nuclear explosion.

In the course of their radioactive decay, the fission products emit gamma rays and another type of nuclear radiation called "beta particles." The latter are identical with electrons, i. e., subatomic particles carrying a negative electric charge moving with high speed. Beta particles, which are also invisible, are much less penetrating than gamma rays, but like the latter they also represent a potential hazard.

The spontaneous emission of beta particles and gamma rays from radioactive substances, such as the fission products, is a gradual process. It takes place over a period of time, at a rate depending upon the nature of the material and upon the amount present. Because of the continuous decay, the quantity of radioactive material and the rate of emission of radiation decreases steadily. This means that the residual nuclear radiation, due mainly to the fission products, is most intense soon after the explosion but diminishes in the course of time.

TYPES OF NUCLEAR EXPLOSIONS

The immediate phenomena associated with a nuclear explosion, as well as the effects of shock and blast, and thermal and nuclear radiations, vary with the location of

the point of burst in relation to the surface of the earth. For descriptive purposes four types of burst are distinguished, although many variations and intermediate situations can arise in practice. The main types, which will be defined below, are (1) air burst, (2) underwater burst, (3) underground burst, and (4) surface burst. The high altitude bursts carried out experimentally will be touched upon in the concluding paragraph of this section.

Almost at the instant of a nuclear explosion there is formed an intensely hot and luminous mass, roughly spherical in shape, called the "ball of fire" or "fireball." An "air burst" is defined as one in which the bomb is exploded in the air, above land or water, at such a height that the fireball (at maximum brilliance) does not touch the surface of the earth. For example, in the explosion of a 1-megaton bomb the ball of fire may grow until it is nearly 5,800 feet (1.1 mile) across, at maximum brilliance. This means that in the air burst of such a bomb the point at which the explosion occurs is at least 2,900 feet above the earth's surface.

The quantitative aspects of an air burst will be dependent upon the actual height of the explosion, as well as upon its energy yield, but the general phenomena are much the same in all cases. Nearly all of the shock energy appears as air blast, although if the explosion occurs close enough to the surface, there will also be some ground shock. The thermal radiation will travel large distances through the air and will be of sufficient intensity to cause moderately severe burns of exposed skin as far away as 12 miles from a 1-megaton bomb explosion, on a fairly clear day. The warmth may be felt at a distance of 75 miles. For air bursts of higher energy yields, the corresponding distances will, of course, be greater. Since the thermal radiation is largely stopped by ordinary opaque materials, buildings and clothing can provide protection.

The initial nuclear radiations from an air burst will also penetrate a long way in air, although the intensity falls off fairly rapidly at increasing distances from the explosion. Like X-rays, the nuclear radiations are not easily absorbed, and fairly thick layers of materials, preferably of high density are needed to reduce their intensity to harmless proportions. For example, at a distance of

1 mile from the air burst of a 1-megaton nuclear bomb, an individual would probably need the protection of about 1 foot of steel or 4 feet of concrete to be relatively safe from the effects of the initial nuclear radiations.

In the event of a high or moderately high air burst, the fission products remaining after the nuclear explosion will be widely dispersed. The residual nuclear radiations arising from these products will be of minor consequence on the ground. On the other hand, if the burst occurs nearer the earth's surface, the fission products may fuse with particles of earth, much of which will fall to the ground at points close to the explosion. This dirt and other debris will be contaminated with radioactive material and may, consequently, represent a possible danger to living organisms.

If a nuclear explosion occurs under such conditions that its center is beneath the ground or under the surface of water, the situation is described as an "underground burst," respectively. Since some of the effects of these two types of explosions are similar, they will be considered here together as subsurface bursts.

In a subsurface burst, most of the shock energy of the explosion appears as underground or underwater shock, but a certain proportion, which is less the greater the depth of the burst, escapes and produces air blast. Much of the thermal radiation and of the initial nuclear radiations will be absorbed within a short distance of the explosion. The energy of the absorbed radiations will merely contribute to the heating of the ground or body of water. Depending upon the depth of the explosion, some of the thermal and nuclear radiations will escape, but the intensities will be less than for an air burst. However, the residual nuclear radiations now become of considerable significance, since large quantities of earth or water in the vicinity of the explosion will be contaminated with radioactive fission products.

A "surface burst" is regarded as one which occurs either at the actual surface of the land or water or at any height above the surface such that the fireball (at maximum brilliance) touches the land or water. The energy of the explosion will then cause both air blast and ground (or water) shock, in varying proportions, depending upon the height of the burst point above the surface. Upon

this will also depend the amounts of thermal radiation and initial nuclear radiations escaping from the ball of fire. The residual nuclear radiation can be a significant hazard because of the large quantities of contaminated dust or water that result from the nuclear explosion.

Although the four types of burst have been considered as being fairly distinct, there is actually no clear line of demarcation between them. It will be apparent that as the height of the explosion is decreased, an air burst will become a surface burst. Similarly, a surface burst merges into a subsurface explosion at a shallow depth, when part of the ball of fire actually breaks through the surface of the land or water. It is nevertheless a matter of convenience, as will be seen in later chapters, to divide nuclear explosions into the four general types defined above.

A nuclear explosion is associated with a number of characteristic phenomena, some of which are visible, while others are not directly apparent. Certain aspects of these phenomena will depend on the type of burst, e. g., air, surface, or subsurface, as indicated above. In addition, meteorological conditions, such as temperature, humidity, wind, precipitation, and atmospheric pressure may influence some of the observable effects, although the overall characteristics, to be described below, remain unchanged.

In the following discussion, it will be supposed, first, that the explosion takes place in the air at a considerable height above the surface. The modifications resulting from a surface burst will be included. Subsequently, some of the special phenomena associated with underwater and underground bursts will be described.

AIR BURST

Development of certain processes accompanying the typical air burst (Fig. 23) are discussed below.

Immediately following the detonation of a nuclear bomb in the air, an intensely hot and luminous (gaseous) ball of fire is formed. Due to its extremely high temperature, it emits thermal (or heat) radiation capable of causing skin burns and starting fires in flammable material at a considerable distance. The nuclear processes which cause the explosion and the radioactive decay of the fission products are accompanied by harmful nuclear radia-

tions (gamma rays and neutrons) that also have a long range in air. Very soon after the explosion, a destructive shock (or blast) wave develops in the air and moves rapidly away from the fireball.

Fig. 23. Air burst.

When the primary shock (or blast) wave from the explosion strikes the ground, another shock (or blast) wave is produced by reflection. At a certain distance from

ground zero, which depends upon the height of burst and the energy of the bomb, the primary and reflected shock fronts fuse near the ground to form a single, reinforced Mach front (or stem).

At first the height of the Mach front is small, but as the shock front continues to move outward, the height increases steadily. At the same time, however, the overpressure, like that in the original shock wave, decreases correspondingly because of the continuous loss of energy and the ever-increasing area of the advancing front.

The distance from ground zero at which the Mach effect commences varies with the height of burst.

In the low-altitude detonation the Mach front is apparent when the direct shock front has advanced only a few yards from the ball of fire. At the other extreme, in a very high air burst there might be no detectable Mach effect. Significant quantities of thermal and nuclear radiations continue to be emitted from the ball of fire.

Nuclear radiations still continue to reach the ground in significant amounts. But after 3 seconds from the detonation of a 20-kiloton bomb, the fireball, although still very hot, has cooled to such an extent that the thermal radiation is no longer important. Appreciable amounts of thermal radiation still continue to be emitted from the fireball at 11 seconds after a 1-megaton explosion; the thermal radiation emisssion is spread over a longer time interval than for an explosion of lower energy yield.

At 10 seconds after a 20-kiloton explosion the Mach front is over $2^1/_2$ miles from ground zero, and 37 seconds after a 1-megaton detonation it is nearly $9^1/_2$ miles from ground zero. Apart from plaster damage and window breakage, the destructive effect of the blast wave is essentially over. Thermal radiation is no longer important, even for the 1-megaton burst. Nuclear radiation, however, can still reach the ground to an appreciable extent; this consists mainly of gamma rays from the fission products.

The ball of fire is no longer luminous, but it is still very hot and it behaves like a hot-air balloon, rising at a rapid rate. As it ascends, it causes air to be drawn inward and upward, somewhat similar to the updraft of a chimney. This produces strong air currents, called afterwinds, which raise dirt and debris from the earth's surface to

form the stem of what will eventually be the characteristic mushroom cloud.

The hot residue of the bomb continues to rise and at the same time it expands and cools. As a result, the vaporized fission products and other bomb residues condense to form a cloud of highly radioactive particles. The afterwinds, having velocities of 200 or more miles per hour, continue to raise a column of dirt and debris which will later join with the radioactive cloud to form the characteristic mushroom shape. Within about 10 minutes, the bottom of the mushroom head will have attained an altitude of 5 to 15 miles, according to the energy yield of the explosion. The top of the cloud will rise even higher. Ultimately, the particles in the cloud will be dispersed by the wind, and, except under weather conditions involving precipitation, there will be no appreciable local fallout.

Although the atomic cloud is still highly radioactive, very little of the nuclear radiation reaches the ground. This is the case because of the increased distance of the cloud above the earth's surface and the decrease in the activity of the fission products due to natural radioactive decay.

SPECIAL CHARACTERISTICS OF A SURFACE BURST

Since many of the phenomena and effects of a nuclear explosion occurring on the earth's surface are similar to those associated with an air burst, it is convenient before proceeding further to refer to some of the special characteristics of the former. In a surface burst, the ball of fire, in its rapid initial growth, will touch the surface of the earth. Because of the intense heat, a considerable amount of rock, soil, and other material located in the area will be vaporazed and taken into the ball of fire. It has been estimated that, if only 5 per cent of a 1-megaton bomb's energy is spent in this manner, something like 20,000 tons of vaporized soil material will be added to the normal constituents of the fireball. In addition, the high winds at the earth's surface will cause large amounts of dirt, dust, and other particles to be sucked up as the ball of fire rises.

An important difference between a surface burst and

an air burst is, consequently, that in the surface burst the atomic cloud is much more heavily loaded with debris. This will consist of particles ranging in size from the very small ones produced by condensation as the ball of fire cools to the much larger particles which have been raised by the surface winds. The exact composition of the cloud will, of course, depend on the nature of the terrain and the extent of contact with the ball of fire.

For a surface burst associated with a moderate amount of debris, such as has been the case in several test explosions, in which the bombs were detonated near the ground, the rate of rise of the cloud is much the same as given earlier for an air burst. The atomic cloud reaches a height of several miles before spreading out into a mushroom shape.

The vaporization of dirt and other material when the ball of fire has touched the earth's surface, and the removal of material by the blast wave and winds accompanying the explosion, result in the formation of a crater. The size of the crater will vary with the height above the surface at which the bomb is exploded and with the character of the soil, as well as with the energy of the bomb. It is believed that, for a 1-megaton bomb, there would be no appreciable crater formation unless detonation occurs at an altitude of 450 feet or less.

In a surface burst, large quantities of earth or water enter the fireball at an early stage and are fused or vaporized. When sufficient cooling has occurred, the fission products become incorporated with the earth particles as a result of the condensation of vaporized fission products into fused particles of earth, etc. A small proportion of the solid particles formed upon further cooling are contaminated fairly uniformly throughout with radioactive fission products and other bomb residues, but in the majority the contamination is found mainly in a thin shell near the surface. In water droplets, the small fission product particles occur at discrete points within the drops. As the violent disturbance due to the exploding bomb subsides, the contaminated particles and droplets gradually fall back to earth. This effect is referred to as the "fallout." It is the fallout, with its associated radioactivity which decays over a long period of time, that is the main source of the residual nuclear radiations.

The extent and nature of the fallout can range between wide extremes. The actual behavior will be determined by a combination of circumstances associated with the energy yield and design of the bomb, the height of the explosion, the nature of the surface beneath the point of burst, and the meteorological conditions. In the case of an air burst, for example, occurring at an appreciable distance above the earth's surface, so that no large amounts of dirt or water are sucked into the cloud, the contaminated particles become widely dispersed. The magnitude of the hazard from fallout in any moderate sized area will then be far less than if the explosion were a surface burst.

On the other hand, a nuclear explosion occurring at or near the earth's surface can result in severe contamination by the radioactive fallout. In the case of the powerful thermonuclear device tested at Bikini Atoll on March 1, 1954, which was detonated close to the surface of a coral island, the ensuing fallout caused substantial contamination over an area of over 7,000 square miles.

The contaminated area was roughly cigar-shaped, extending approximately 20 (statute) miles up-wind and 220 miles down-wind. The width in the cross-wind direction was variable, the maximum being close to 40 miles. Actually, both the direction and the velocity of the wind, particularly in the upper atmosphere, have a significant influence on the shape and extent of the contaminated area. As will be seen later, the wind characteristics must be taken into consideration in attempting to predict the fallout pattern following a nuclear explosion.

It should be understood that the fallout is a gradual phenomenon extending over a period of time. In the Bikini explosion referred to above, for example, several (about 10) hours elapsed before the contaminated particles began to fall at the extremities of the 7,000 square mile area. By that time, the atomic cloud had thinned out to such an extent that it was no longer visible. This brings up the important fact that fallout can occur even when the radioactive atomic cloud cannot be seen. Nevertheless, most of the fallout generally results from the larger contaminated particles of dirt and debris which drop from the mushroom cloud at distances not too far from the region of the explosion. This is referred to as the "local fallout." There is, in addition, another kind of fal-

lout, consisting of very fine particles which descend very slowly and eventually cover large areas in a fairly uniform manner. This is the "world-wide fallout" to which the residues from nuclear explosions of all types — air, surface, and subsurface — may contribute.

Of course, special circumstances might arise in which there would be appreciable local fallout even with an air burst. If it were to rain at the time of, or soon after, the explosion, the raindrops would carry down with them some of the radioactive particles.

DESCRIPTION OF AN UNDERWATER BURST

Although there are certain characteristic phenomena associated with an underwater nuclear explosion, the details will undoubtedly vary with the energy yield of the bomb, the distance below the surface at which the detonation occurs, and the depth and area of the body of water.

In an underwater nuclear detonation, a ball of fire is formed, but it is probably smaller than in the case of an air burst. The water in the vicinity of the explosion is lighted up by the luminosity of the ball of fire. The luminosity remains for a few thousandths of a second, but it disappears as soon as the bubble of hot, high-pressure gases constituting the ball of fire reaches the water surface. At this time, the gases are expelled and cooled, so that the fireball is no longer visible.

In the course of its rapid expansion, the hot gas bubble, while still under water, initiates a shock wave. The trace of this wave, as it moves outward from the burst, is evident, on a reasonably calm surface, as a rapidly advancing circle, apparently whiter than the surrounding water. This phenomenon, sometimes called the "slick," is visible in contrast to the undisturbed water because small droplets of water at the surface are hurled short distances into the air, and the resulting entrainment of air makes the shocked water surface look white.

Following immediately upon the appearance of the slick, and prior to the formation of the Wilson cloud, a mound or column of broken water and spray, called the "spray dome," is thrown up over the point of the burst. This is a consequence of the reflection of the shock wave

at the surface. The initial upward velocity of the water is proportional to the pressure of the direct shock wave, and so it is greatest directly above the detonation point. Consequently, the water in the center rises more rapidly (and for a longer time) than water farther away. As a result, the sides of the spray dome become steeper as the water rises. The upward motion is terminated by the downward pull of gravity and the resistance of the air. The total time of rise and the maximum height attained depend upon the energy of the explosion, and upon its depth below the water surface. For a very deep underwater burst, the spray dome may not be visible at all.

If the depth of burst is not too great, the bubble of hot, compressed gases remains essentially intact until it rises to the surface of the water. At this point the gases, carrying some liquid water by entrainment, are expelled into the atmosphere. Part of the shock wave passes through the surface into the air and because of the high humidity, the conditions are suitable for the formation of a condensation cloud. As the pressure of the bubble is released, water rushes into the cavity, and the resultant complex phenomena cause the water to be thrown up as a hollow cylinder or chimney of spray called the "column." The radioactive contents of the gas bubble are vented through this hollow column and form a cauliflower-shaped atomic cloud, partly obscuring the top of the column. The cloud is highly radioactive, due to the presence of fission products, and hence it emits nuclear radiations. Because of the height of the cloud these radiations are a minor hazard to persons near the surface of the water.

At 10 to 12 seconds after a shallow underwater explosion, the water falling back from the column reaches the surface and produces around the base of the column a ring of highly radioactive mist, called the "base surge."

The base surge is essentially a dense cloud of water droplets, much like the spray at the base of high waterfalls, but having the property of flowing almost as if it were a homogeneous fluid.

After about 5 minutes, the base surge had the appearance of a mass of strato-cumulus clouds which eventually reached a thickness of several thousand feet. A moderate to heavy rainfall, moving with the wind and lasting for

nearly an hour, developed from the cloud mass. In its early stages the rain was augmented by the small water droplets still descending from the atomic cloud.

From the weapons effects standpoint, the importance of the base surge lies in the fact that it is likely to be highly radioactive due to fission products present either at its inception, or dropped into it from the atomic cloud. Because of its radioactivity, it may represent a serious hazard for a distance of several miles, especially in the downwind direction. Any object over which the base surge passes is likely to become contaminated, due to the deposition of water droplets to which fission products may have become attached. The base surge and the fallout or "rainout" from the atomic cloud constitute the sources of the residual nuclear radiation following an underwater nuclear explosion.

The disturbance due to the underwater explosion causes large water waves to form on the surface. At 12 seconds after a 100-kiloton explosion, the first of these is about 1,800 feet (0.34 mile) from surface zero, and its height, from crest to trough, is 176 feet.

Essentially all the thermal radiation emitted by the ball of fire while it is still submerged is absorbed by the surrounding water. When the hot gases reach the surface and expand, the cooling is so rapid that the temperature drops almost immediately to a point where there is no further appreciable emission of thermal radiation. It follows, therefore, that in an underwater nuclear explosion the thermal radiation can be ignored, as far as its effects on personnel and as a source of fire are concerned.

It is probable, too, that most of the neutrons and gamma rays liberated within a short time of the initiation of the explosion will also be absorbed by the water. But, when the fireball reaches the surface and the gases are expelled, the gamma rays (and beta particles) from the fission products will represent a form of initial nuclear radiation. In addition, the radiation from the fission (and induced radioactive) products, present in the column, atomic cloud, and base surge, all three of which are formed within a few seconds of the burst, will contribute to the initial effects.

However, the water fallout (or rainout) from the cloud and the base surge are also responsible for the residual

nuclear radiations, as described above. For an underwater burst, it is thus less meaningful to make a sharp distinction between initial and residual radiations, such as is done in the case an air burst. The initial nuclear radiations merge continuously into those which are produced over a period of time following the nuclear explosion.

SPECIAL CHARACTERISTICS OF AN UNDERGROUND BURST

When a nuclear explosion occurs at a shallow depth underground, the ball of fire breaks through the surface of the earth within a fraction of a second of the instant of detonation. As the fireball penetrates the surface, the intensely hot gases at high pressure are released and they carry up with them into the air large quantities of soil, rock, and debris in the form of a hollow column. For a burst at a shallow depth; the column tends to assume the shape of an inverted cone which fans out as it rises to produce a radial throwout. A highly radioactive cloud, which contains large quantities of earth, is formed above the throwout as the hot vapors cool and condense. Because of the mass displacement of material from the earth's surface, a crater is formed. For a 100-kiloton bomb exploding 50 feet beneath the surface of dry soil, the crater would be about 120 feet deep and 720 feet across. The weight of the material removed would be over a million tons.

In addition to the shock (or pressure) wave in the ground, somewhat related to an earthquake wave, the explosion is accompanied by a shock (or blast) wave in the air. At 2 seconds after the explosion, the shock front in the air is about $^{3}/_{4}$ mile from surface zero.

The atomic cloud continues to rise, giving off intense nuclear radiations which are still a hazard on the ground at 9 seconds after the detonation. At this time, the larger pieces of rock and debris in the throwout begin to descend to earth.

As the material from the column descends, the finer soil particles attain a high velocity and upon reaching the ground they spread out rapidly to form a base surge similar to that in an underwater explosion. The extent of the base surge, which is likely to be radioactive, depends upon many factors, including the energy yield of the ex-

plosion, the depth of burst, and the nature of the soil. It is believed that a dry sandy terrain will be particularly conducive to base surge formation.

The base surge increases in height and area and soon begins to merge with the atomic cloud of bomb residues, etc., part of which descends and spreads out under the influence of the prevailing winds. In due course, the radioactive clouds disperse, but the contaminated particles descend to earth to produce a hazardous fallout over a large area, especially in the downwind direction, during the course of a few hours.

The situation as regards thermal and nuclear radiations from an underground burst are quite similar to those described above in connection with an underwater explosion. As a general rule, the thermal radiation will be almost completely absorbed by the soil material, so that it does not represent a significant hazard. Most of the neutrons and early gamma rays will also be removed, although the capture of the neutrons may cause a considerable amount of induced radioactivity in various materials present in the soil. This will constitute a small part of the residual nuclear radiation, of importance only in the close vicinity of the point of burst. The remainder of the residual radiation will be due to the contaminated base surge and fallout.

HIGH-ALTITUDE BURST

The following description of the high-altitude burst is based on the data obtained at the "Hardtack" test series in the Pacific Ocean in the summer of 1958. Two nuclear devices — "Teak" and "Orange" — in the megaton range were exploded in the vicinity of Johnston Island, 700 miles southwest of Hawaii. "Teak" was detonated at an altitude of 252,000 feet, i. e., nearly 50 miles, while "Orange" was detonated at an altitude of 141,000 feet, i. e., nearly 27 miles.

The "Teak" and "Orange" high-altitude nuclear explosions created spectacular visible effects both locally and at great distances. These effects were observed from Johnston Island and its vicinity, close to the explosion, and at remote points such as Hawaii and the Samoa Islands. In addition, the detonations caused widespread disturban-

ces in that portion of the upper atmosphere known as the ionosphere, and this affected the propagation of radio waves and other similar electromagnetic radiations of relatively long wave lengths (see Section IV of this Part).

The "Teak" burst was accompanied by a sharp and bright flash of light which was visible in the sky above the horizon in Hawaii. Because of the weak interaction of the thermal and nuclear radiations and the kinetic energy of the fission products with the ambient, low-density atmosphere, the fireball which developed grew very rapidly in size. In .3 second, its diameter was already 11 miles and it increased to 19 miles in 3.5 seconds. The fireball also ascended with great rapidity, the initial rate of rise being about a mile per second. Surrounding the fireball was a very large red luminous spherical wave apparently produced by passage of a shock front through the low-density air.

At about a minute or so after the detonation, the "Teak" fireball had risen to a height of over 90 miles and it was then directly (line-of-sight) visible from Hawaii, over 700 miles away. The rate of rise of the fireball was estimated to be some 3,300 feet per second and it was expanding horizontally at a rate of about 1,000 feet per second. The large red luminous sphere was observed for a few minutes; at roughly 6 minutes after the explosion it was nearly 600 miles in diameter.

An interesting visible effect of the "Teak" shot was the creation of an "artificial aurora." Within a second or two after the burst time a brilliant aurora appeared from the bottom of the fireball and purple streamers were seen to spread toward the north. About a minute after the detonation an aurora was observed at a point more than 2,000 miles from the point of burst, although at no time was the fireball in direct view. The formation of the aurora is attributed to the motion along the lines of the earth's magnetic field of beta particles (electrons) emitted by radioactive fission fragments.

The "Orange" shot created a fireball almost spherical in shape. It grew in size much more slowly than that from the "Teak" burst, which was at a higher altitude and consequently at lower atmospheric density. In general the fireball behavior was in agreement with the somewhat stronger interaction of the various radiations and kinetic

energy and the ambient air at higher density than in "Teak" shot. As seen from Hawaii the "Orange" explosion produced a bright flash in the sky above the horizon lasting for a fraction of a second. About a minute later, a grayish-white radioactive cloud was observed low on the horizon, but it disappeared within 4 minutes.

Section III

CHARACTERISTICS OF AIR BLAST, THERMAL RADIATION, NUCLEAR RADIATION AND RADIOACTIVE CONTAMINATION

AIR BLAST

As already seen in Section II, the expansion of the intensely hot gases at extremely high pressures in the ball of fire causes a blast wave to form in the air, moving outward at high velocity.

For a short interval after the detonation there will be no increase in pressure, since it takes the blast wave some time to travel the distance from the point of the explosion to the given location. When the shock arrives, the pressure will suddenly increase to a large value, i. e., to the peak overpressure.

The fairly sharp boundary between the pressure disturbance created by an explosion and the ambient atmosphere constitutes the front of the shock wave. The maximum value, i. e., at the shock front, is called the peak overpressure which is the main characteristics of the blast wave.

Other characteristics of the blast wave such as dynamic pressure, duration, and time of arrival depend on the peak overpressure. The pressure inside the shock front near ground zero reaches many thousand atmospheres. As the blast wave travels in the air away from its source, the overpressure at the front steadily decreases.

As stated previously, there is a finite time interval required for the blast wave to move out from the explosion center to any particular location. This time interval (or arrival time) is dependent upon the energy yield of the explosion and the distance involved; thus, at 1 mile from a 1-megaton burst, the arrival time would be about 4 se-

conds. Initially, the velocity of the shock front is quite high, many times the speed of sound, but as the blast wave progresses outward, it slows down as the shock front weakens. Finally, at long ranges, the blast wave becomes essentially a sound wave and its velocity approaches ambient sound velocity.

The duration of the blast wave at a particular location also depends on the energy of the explosion and the distance from the point of burst. The positive phase duration is shortest at close ranges and increases as the blast wave moves outward. At 1 mile from a 1-megaton explosion, for example, the duration of the positive phase of the blast wave is about 2 seconds. There is a minimum positive duration associated with blast wave development which occurs prior to the formation of a negative phase.

When the incident blast wave from an explosion in air strikes a more dense medium such as the earth's surface, e. g., either land or water it is reflected forming a reflected shock wave. In the region near ground zero this total reflected overpressure will be more than twice the value of the peak overpressure of the incident blast wave.

SCALING LAWS

In order to be able to calculate the characteristic properties of the blast wave from an explosion of any given energy if those for another energy are known, appropriate scaling laws are applied. With the aid of such laws it is possible to express the data for a large range of energies in a simple form.

Theoretically, a given pressure will occur at a distance from an explosion that is proportional to the cube root of the energy yield. Full scale tests have shown this relationship between distance and energy yield to hold for yields up to (and including) the megaton range. Thus, cube root scaling may be applied with confidence over a wide range of explosion energies. According to this law, if D_1 is the distance from a reference explosion of W_1 kilotons at which a certain overpressure of dynamic pressure is attained, then for any explosion of W kilotons

energy these same pressures will occur at a distance D given by

$$\frac{D}{D_1} = \left(\frac{W}{W_1}\right)^{\frac{1}{3}}$$

The reference explosion is conveniently chosen as having an energy yield of 1 kiloton, so that $W_1 = 1$. It follows therefore, from the equation given above, that

$$D = D_1 \times W^{\frac{1}{3}}$$

where D_1 refers to the distance from a 1-kiloton explosion. Consequently if the distance D is specified then the value of the explosion energy, W, required to produce a certain effect, e. g., a given peak overpressure can be calculated. Alternatively, if the energy, W, is specified, the appropriate distance, D, can be evaluated.

When comparing air bursts having different energy yields it is convenient to introduce a scaled height of burst, defined as

$$\text{Scaled height of burst} = \frac{\text{actual height of burst}}{W^{\frac{1}{3}}}$$

It can be readily seen, therefore, that for explosions of different energies having the same scaled height of burst, the cube root scaling law may be applied to distances from ground zero as well as to distances from the explosion.

Thus if D_1 is the distance from ground zero at which a particular overpressure of dynamic pressure occurs for 1-kiloton explosion, than for an explosion of W kilotons energy the same pressures will be observed at a distance D determined by the relationship

$$D = D_1 \times W^{\frac{1}{3}}$$

THERMAL RADIATION

As a consequence of the high temperatures in the ball of fire, similar to those in the center of the sun, a considerable fraction of the nuclear energy appears as thermal radiation.

From the standpoint of this radiation, the fireball in a nuclear explosion resembles the sun in many respects. The radiation in each case is made up of ultraviolet rays of short wave length, visible light of longer wave length, and infrared radiation of still longer wave length. Thermal radiation travels with the speed of light, i. e., 186,000 miles per second, so that the time elapsing between its emission from the ball of fire and its arrival at a target a few miles away, is quite insignificant.

The duration of the thermal radiation depends on the power of the explosion. With the nominal bomb it lasts for about 3 seconds. Bombs of the megaton range produce thermal radiation lasting for 10--20 or more seconds.

The radiations from the ball of fire, like the sun's rays, are attenuated as they pass through the air. The amount of thermal radiation from a particular nuclear explosion that will reach a given point depends upon the distance from the burst and upon the condition of the intervening atmosphere.

The extent of injury or damage caused by thermal radiation or the chances of igniting combustible material depend to a large extent upon the amount of thermal radiation energy received by a unit area of skin, fabric, or other exposed material. The thermal energy falling upon a given area from a specified explosion will be less the farther from the explosion, for two reasons: the spread of the radiation over an ever increasing area as it travels away from the fireball, and attenuation of the radiation in its passage through the air.

Unless scattered, thermal radiation from a nuclear explosion, like ordinary light in general, travels in straight lines from its source, the ball of fire. Any solid, opaque material, such as a wall, a hull, or a tree, between a given object and the fireball will thus act as a shield and provide protection from thermal radiation. Transparent materials, on the other hand, such as glass or plastics, allow thermal radiation to pass through only slightly attenuated.

A shield which merely intervenes between a given target and the ball of fire, but does not surround the target, may not be entirely effective under hazy atmospheric conditions. A large proportion of the thermal radiation received, especially at considerable distances from the

explosion, has undergone scattering and will arrive from all directions, not merely that from the point of burst. This situation should be borne in mind in connection with the problem of thermal radiation shielding.

In subsurface bursts, either in the earth or under water, nearly all the thermal radiation is absorbed, provided there is no appreciable penetration of the surface by the ball of fire. Normal thermal radiation effects, such as accompany an air burst, are thus absent.

Although blast is responsible for most of the destruction caused by a nuclear air burst, thermal radiation will contribute to the overall damage by igniting combustible materials, e. g., finely divided or thin fuels such as dried leaves and newspapers, and thus starting fires in buildings or forests.

The effects of the thermal radiation are described in greater detail in Section IV of this Part.

NUCLEAR RADIATION

It was stated that one of the unique features of a nuclear explosion is the fact that it is accompanied by the emission of nuclear radiation. These radiations, which are quite different from the thermal radiation discussed in the preceding chapter, consist of gamma rays, neutrons, beta particles, and a small proportion of alpha particles. Most of the neutrons and some of the gamma rays are emitted in the actual fission process, that is to say, simultaneously with the explosion, whereas the beta particles and the remainder of the gamma rays are liberated as the fission products decay. Some of the alpha particles result from the normal radioactive decay of the uranium or plutonium that has escaped fission in the bomb, and others (helium nuclei) are formed in hydrogen fusion reactions.

Because of the nature of the phenomena associated with a nuclear explosion, either in the air or near the surface, it is convenient, for practical purposes, to consider the nuclear radiations as being divided into two categories, namely, initial and residual. The line of demarcation is somewhat arbitrary, but it may be taken as about 1 minute after the explosion. The initial nuclear radiation, with which the present chapter will be concerned, consequently refers to the radiation emitted within 1 minute of

the detonation. For underground or underwater explosions, it is less meaningful to separate the initial from the residual nuclear radiation although the distinction may be made if desired.

The ranges of alpha and beta particles are comparatively short and they cannot reach the surface of the earth from an air burst. Even when the ball of fire touches the ground, the alpha and beta particles are not very important. The initial nuclear radiation may thus be regarded as consisting only of the gamma rays and neutrons produced during a period of 1 minute after the nuclear explosion.

Although neutrons are nuclear particles of appreciable mass whereas gamma rays are electromagnetic waves, analogous to X-rays, their harmful effects on the body are similar in character. Both of these nuclear radiations can penetrate considerable distances through the air.

Essentially all the neutrons accompanying a nuclear explosion are released either in the fission or fusion process. Almost all of the neutrons are produced almost immediately, probably within less than a millionth of the second of the initiation of explosion.

Most of the gamma rays in the initial nuclear radiation are produced in the fission process and the radioactive fission products decay. The duration of the gamma radiation is limited to a minute for reasons given earlier.

As far as the initial nuclear radiation is concerned it is the total dose that is the important quantity. The total dose is the sum of the gamma and neutron radiations. The radiation dosage is measured in roentgens.

Exposure dose of the initial radiation at a particular location is less the farther that location is from the point of burst. The relationship of the radiation dose to the distance is dependent upon two factors, analogous to those which apply to thermal radiation. There is, first, the general decrease, due to the spread of the radiation over larger and larger areas as it travels away from the nuclear explosion. In addition, there is an attenuation factor to allow for the decrease in intensity due to absorption and scattering of gamma rays and neutrons by the intervening atmosphere.

Gamma rays and neutrons are absorbed (or attenuated) to some extent in the course of their passage through

any material. Strictly speaking, it is not possible to absorb gamma ray~~s and neutrons~~ completely. Nevertheless, if a sufficient thickness of matter is interposed between the radiation source, such as an exploding nuclear bomb, and an individual, the exposure dose can be reduced to negligible proportions.

The effectiveness of a given material in decreasing the radiation intensity can be conveniently represented by a quantity called the "half-value layer thickness." This is the thickness of the particular material which absorbs half the gamma radiation falling upon it. Thus, if a person were in a position where the exposure dose is 400 roentgens, e. g., of initial gamma radiations, with no shielding, the introduction of a half-value layer of any material would decrease the dose to (approximately) 200 roentgens. The addition of another half-value layer would again halve the dose, i. e., to (approximately) 100 roentgens. Each succeeding half-value layer thickness decreases the radiation dose by half. One half-value layer decreases the radiation dose to half of its original value; two half-value layers reduce it to one-quarter; three half-value layers to one-eighth; four half-value layers to one-sixteenth, and so on.

The chief materials likely to be available for shielding against the initial nuclear radiation from a nuclear explosion are steel, concrete, earth, and wood.

In general, concrete or damp earth would represent a fair compromise for neutron as well as for gamma ray shielding. Because of the scattering suffered by gamma rays complete protection shelters must be shielded in all directions.

The residual nuclear radiation is defined, for reasons given earlier, as that emitted after 1 minute from the instant of a nuclear explosion. This radiation arises mainly from the bomb residues, that is, from the fission products and, to a lesser extent, from the uranium and plutonium which have escaped fission. In addition, the residues will usually contain some radioactive isotopes formed as a result of neutron capture by the bomb materials. Another source of residual nuclear radiation is the activity induced by neutrons captured in various elements present in the earth, in the sea, or in substances which may be in the explosion environment. It may be mentioned, in passing,

that radioactivity induced by the gamma rays from a nuclear explosion is either insignificant or completely absent.

In the case of an air burst, particularly when the ball of fire is well above the earth's surface, a fairly sharp distinction can be made between the initial nuclear radiation, and the residual radiation. The reason is that, by the end of a minute, essentially all of the bomb residues, in the form of very small particles, will have risen to such a height that the nuclear radiations no longer reach the ground in significant amounts. Subsequently, the fine particles are widely dispersed in the atmosphere and descend to earth very slowly.

With surface and, especially, subsurface explosions, the demarcation between initial and residual nuclear radiations is not as definite. Some of the radiations from the bomb residues will be within range of the earth's surface at all times, so that the initial and residual categories merge continuously into one another. For very deep underground and underwater bursts the initial gamma rays and neutrons produced in the fission process may be ignored. Essentially the only nuclear radiation of importance is that arising from the bomb residues. It can, consequently, be treated as consisting exclusively of the residual radiation. In a surface burst, however, both initial and residual nuclear radiations must be taken into consideration.

The fission products constitute a very complex mixture of some 200 different forms (isotopes) of 35 elements. Most of these isotopes are radioactive, decaying by the emission of beta particles, frequently accompanied by gamma radiation. About $1^3/_4$ ounces (0.11 pound) of fission products are formed for each kiloton (or 110 pounds per megaton) of fission energy yield. The total radioactivity of the fission products initially is extremely large, but it falls off at a fairly rapid rate as the result of decay.

The neutrons liberated in the fission process, but which are not involved in the propagation of the fission chain, are ultimately captured by the bomb materials through which they must pass before they can escape, by nitrogen (especially) and oxygen in the atmosphere, and by various elements present in the earth's surface. As a result of capturing neutrons many substances become radioactive. They, consequently, emit beta particles, frequently

accompanied by gamma radiation, over an extended period of time following the explosion. Such neutron-induced activity, therefore, is part of the residual nuclear radiation.

The uranium and plutonium which may have escaped fission in the nuclear bomb represent a further possible source of residual nuclear radiation. The fissionable isotopes of these elements emit alpha particles and also some gamma rays of low energy. However, because of their very long half-lives, the activity is very small compared with that of the fission products.

The alpha particles from uranium and plutonium, or from radioactive sources in general, are completely absorbed in an inch or two of air. This, together with the fact that the particles cannot penetrate ordinary clothing, indicates that uranium and plutonium deposited on the earth do not represent a serious external hazard. Even if they actually come in contact with the body, the alpha particles emitted are unable to penetrate the unbroken skin.

Although there is negligible danger from uranium and plutonium outside the body, the situation might be different if either of these elements entered the body through the lungs, the digestive system, or breaks in the skin. Plutonium, for example, tends to concentrate in bone, where the prolonged action of the alpha particles may cause serious harm.

Thus the residual nuclear radiation is constituted by the emission of alpha and beta particles and gamma rays.

In considering the radiation dose (or dose rate) of the residual radiation the gamma rays, because of their long range and penetrating power, are of greater significance than the beta particles, provided the radioactive material is not actually on the skin or within the body. Consequently, the beta radiation can be neglected in estimating the variation with time of the dose rate from the residual nuclear radiation.

Both residual and initial radiations have harmful effects on the human body.

If injury is to be minimized, definite action of some kind must be taken to attenuate the residual radiation from external sources. Incidentally, any method used to decrease the gamma radiation will also result in a much greater attenuation of both alpha and beta particles.

There are two main ways in which the earth's surface can become contaminated with radioactive material as a result of a nuclear explosion. One is by the induced activity following the capture of neutrons by various elements present in the soil (or sea), and the other is by the fallout, that is, by the subsidence of radioactive particles from the column and cloud formed in the explosion. Both the relative and actual importance of these two sources of contamination depend very greatly upon the location of the point of burst with regard to the surface of the earth, and also upon the energy yield of the explosion. Other factors which may affect the contamination are the nature of the terrain and meteorological conditions.

In an air burst the radioactive bomb residues, consisting largely of the fission products, condense into very small solid particles. In this finely divided state a portion of the radioactive particles enter the stratosphere and will remain suspended for many years, even circling the earth several times, before descending to the surface. During this period they undergo decay and loss of activity. Hence, when the particles do reach the earth's surface, they will be widely dispersed and their radioactivity will be very greatly reduced. In fact the external radiation produced by the fallout from a weapon with a fission yield in the megaton range would be extremely small in comparison with the natural background radiation.

Under certain meteorological conditions, e. g., abnormal winds or a rainfall situation, there might be appreciable fallout, probably of a localized character. For example, in a moist atmosphere the fine particles of bomb residue could attach themselves to water droplets which might subsequently fall as radioactive rain.

An air burst of a small yield weapon would not be accompanied by serious local fallout except possible in unusual circumstances. Observations made at tests indicate that the local fallout from air bursts is also small for large yield weapons.

An important source of contamination due to residual nuclear radiation from an air burst can be the activity induced by neutrons captured by elements, notably sodium and manganese, on the earth's surface. The amount of the

contamination, which will be appreciable only in a limited area about ground zero, will depend upon the height of burst, the energy yield, and the time elapsed since the explosion.

A low air burst of a nuclear weapon of high energy could result in extensive contamination due to induced activity in the vicinity of ground zero. In this region, destruction by blast and fire, except for strong underground structures, would be virtually complete.

In an air burst, the neutron-induced activity may be significant, but the local fallout, soon after the explosion, will generally be unimportant. The fission products will, however, contribute to the activity of the gradual fallout extending over large areas. With a surface (or subsurface) burst, on the other hand, the local fallout will assume major significance. Although there will undoubtedly be a considerable amount of induced radioactivity near ground zero, the activity of the fission product fallout will be so much greater in a surface burst that the induced activity can be neglected in comparison. Consequently, the subsequent discussion of the residual radiation following a surface burst will deal mainly with the (local) fallout of fission products.

The fraction of the total radioactivity of the bomb residues that appears in the fallout depends upon the extent to which the ball of fire touches the surface. Thus, the proportion of the available activity increases as the height of burst decreases and more of the fireball comes into contact with the earth. In the case of a contact burst, i. e., one in which the bomb is actually on the surface when it explodes, some 50 per cent of the total residual radioactivity will be deposited on the ground within a few hundred miles of the explosion. The remainder of the activity will stay suspended for a long time and will eventually reach the earth many hundreds or thousands of miles away, as in the case of an air burst.

The fallout of particles of moderate and small size will form, in the course of time, a kind of elongated (or cigar-shaped) pattern of contamination. The shape and dimensions will be determined by the wind velocities and directions at all altitudes between the ground and the atomic cloud.

In Fig. 24 an attempt is made to generalize the pat-

tern of contamination due to the residual nuclear radioactivity from a nuclear explosion near the earth's surface. The figure shows the ground zero (GZ) circle, corresponding to a particular dose rate (or total dose) of nuclear radiation at a specified time. Its center is somewhat displaced from actual ground zero by the wind in the vicinity of the explosion. The ellipse, with its long axis in the direction of the effective wind, is a simplified dose-rate (or dose) contour for the fallout.

The contour will assume the shape of the ellipse when the fallout is completed. This requires some time; the

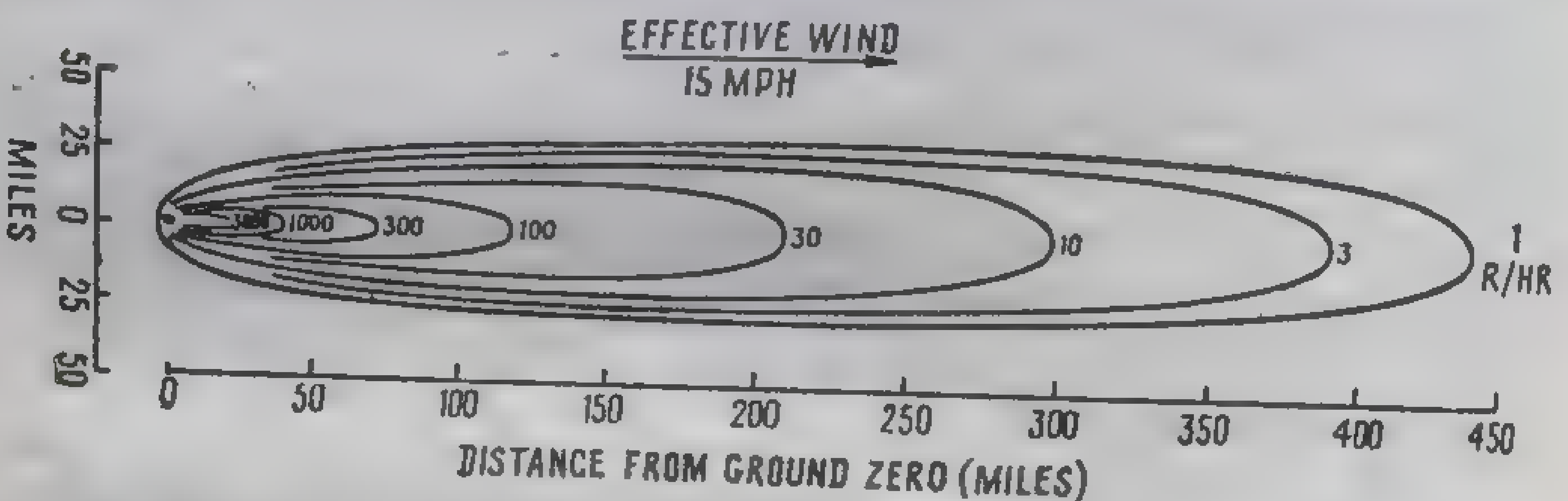

Fig. 24. Idealized fallout pattern. Unit-time reference dose-rate pattern for early fallout from 1-megaton fission yield surface burst.

length of it will depend on the distance from ground zero, the time taken for the particles to descend to earth and effective wind velocity. The radioactive decay will, in the course of time, lead to the decrease in the active area with a given dose rate.

TOTAL DOSE CALCULATION

To operate successfully in an area of fallout it is necessary to estimate the nuclear radiation hazard to which the troops may be exposed in various situations. The procedure for making staff estimates of the radiation hazard is to determine the amounts of radiation — total doses — likely to be received during operations.

Total radiation doses, principally a result of body exposure to gamma radiation from fallout, involve these variables:

The time after detonation of initial exposure to fallout. This "time" can be the arrival of fallout particles in an

occupied area or the deliberate entry of personnel into an area already contaminated. This variable is termed "entry time."

The length or duration of exposure or "stay time."

The "dose rate" of the radiation at the time of entry.

The degree of radiation protection of shielding, such as tanks, foxholes, and buildings, available to the individual or unit.

When the values of these variables can be determined, total radiation doses may be calculated quickly with the aid of the nomograms shown in Fig. 25 and 26.

Let us assume that troops in armored carriers enter a fallout area six hours after the detonation (entry time). Radiac meters measure the dose rate outside of the carriers as 24 r/hr (roentgens per hour). The commander has specified that these troops should not receive a total radiation dose greater than 27 r (roentgens) during their stay in the fallout area. The problem is to determine the maximum length of stay in the area (stay time) in which the troops will accumulate no more than the specified allowable total dose of 27 r.

Solution:

Step 1.— Since the total dose nomogram (Fig. 25) is based on a dose rate at H + 1 hours (DR_1), the measured dose rate at H + 6(DR_6) must be related to H + 1 by application of "decay." This is calculated by using the following table and a straightedge.

Align the straightedge with "24" on the left scale (DR_1) and "6" on the center (Time After Burst, Fallout) scale. Read "200 r/hr" on the right (DR_1) scale.

Step 2.— Since the dose rate was measured outside of the armored carriers the inside exposure rate must be computed. Determine the transmission factor (shielding) for armored carriers from the Table to be 0.25 for residual radiation (fallout). Apply this factor to the DR_1 computed in Step 1 or $0.25 \times 200 = 50$ r/hr.

Thus far we have the values for three of the total dose variables:

Entry time = H + 6.

DR_1 (in armored carriers) = 50 r/hr.

Total dose = 27 r, specified by the commander.

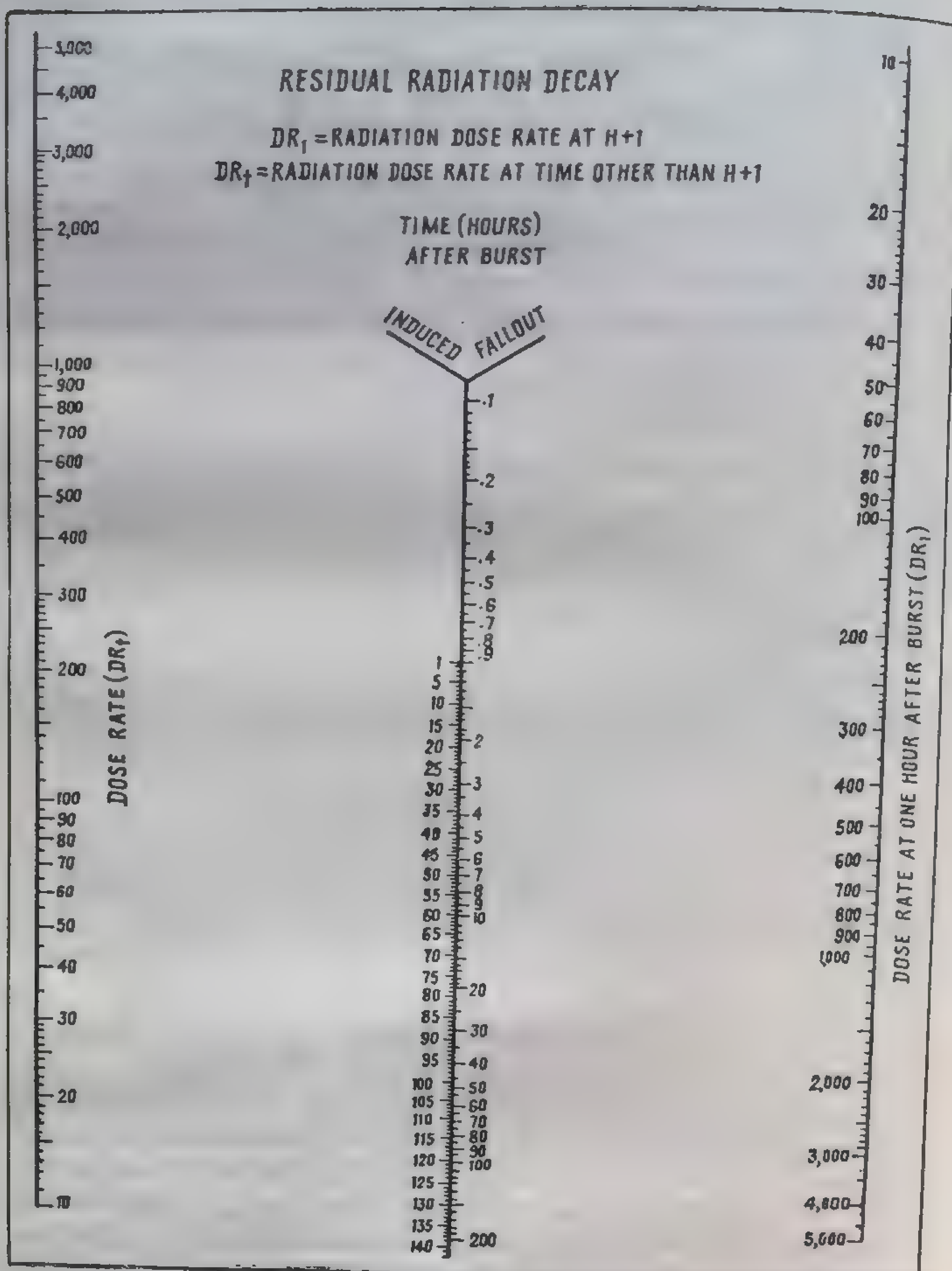

Fig. 25. Residual radiation decay.

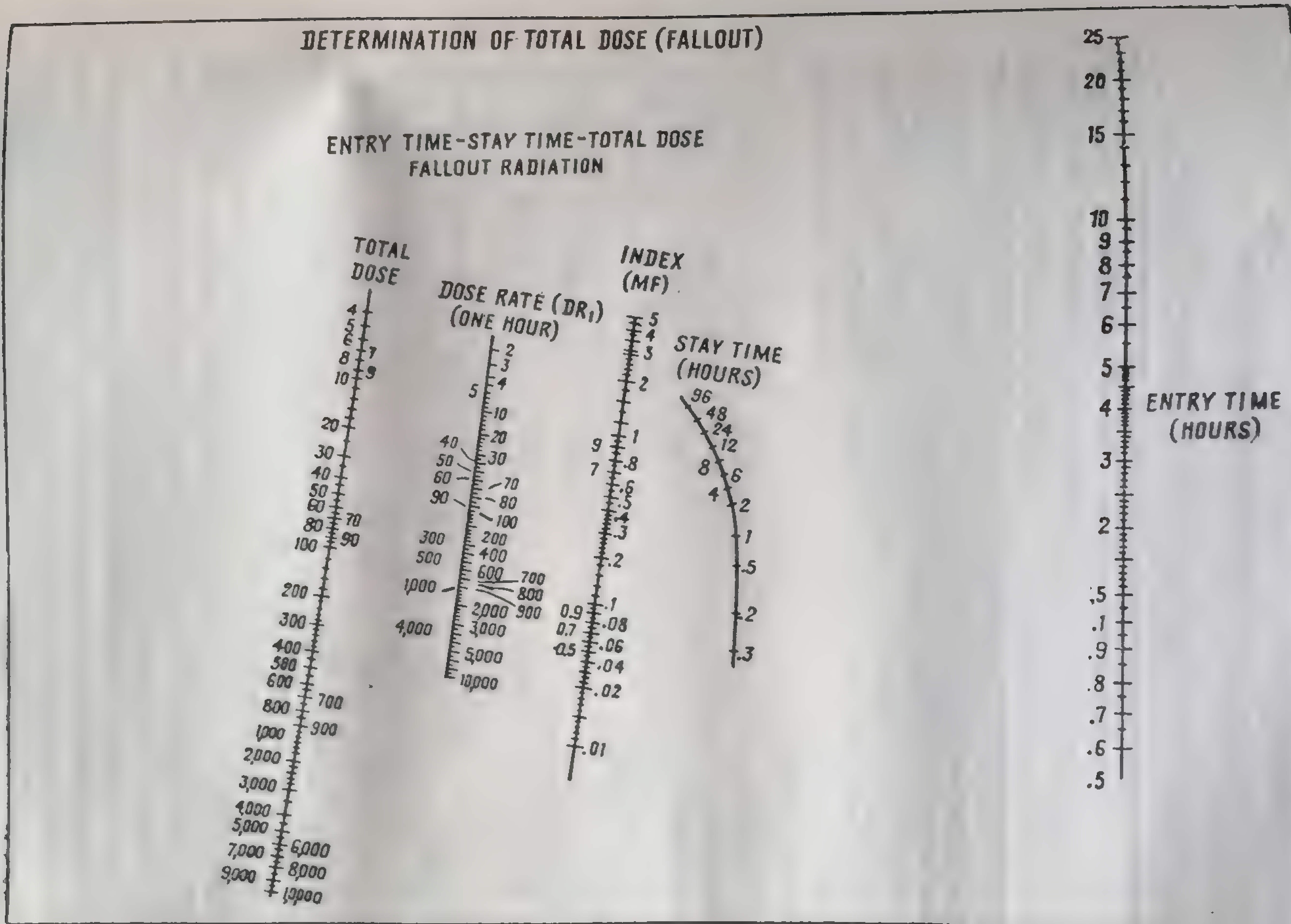

Fig. 26. Determination of total dose (fallout).

We can now solve our problem of determining the maximum permissible stay time.

Transmission factors for nuclear radiation

(ratio of protected to unprotected dose or dose rate)

Environment	Initial		Residual
	Neutrons	Gamma	
Armored carrier	0.8	0.6	0.25
Urban area (in open)	1.0	0.5	0.8
Foxholes	0.25	0.1	0.2
Framehouse			
First floor	1.0	0.7	0.5
Basement	0.7	0.4	0.1
Multistory buildings			
Top floor	1.0	0.7	0.5
Lower floors	0.7	0.4	0.1
Basement	0.5	0.25	0.01
Rough terrain	1.0	1.0	0.8
Shelter, closed (three foot earth cover)	0.1	0.01	0.001
Tanks			
Light	0.7	0.33	0.15
Medium or heavy	0.5	0.15	0.05
Trucks			
1/4-ton	1.0	1.0	0.8
2 1/2-ton	1.0	0.9	0.6
Woods	1.0	1.0	0.8

Step 3.—Using Fig. 26 align the straightedge with "27" on the Total Dose scale and "50" on the DR_1 scale. Note that it intersects "0.5" on the Index (multiplying factor MF) scale. Now align the straightedge with this point (0.5) and "6" on the Entry Time scale and read a stay time of "8 hours."

This example typifies the information required to make decisions involving operations in a fallout area. Other situations may require decisions as to the "earliest safe entry time" and the "degree of protection" or "shielding" that must be provided personnel in order that a specified total dose will not be exceeded during a required stay time.

Section IV

EFFECTS OF NUCLEAR EXPLOSION ON MATERIAL, EQUIPMENT AND STRUCTURES

The chief and most important effects of a nuclear explosion are those caused by the blast. These are very much similar to the effects of the blast caused by the explosion of the conventional weapon except that the former are many times more powerful. The nuclear explosion will cause destruction of material, equipment and structures of different types over wide areas. The extent of damage will be dependent primarily on the weapon's yield. Actual physical damage to structures and equipment will be mainly due to air blast and thermal radiation. Initial and residual radiations produce no mechanical destruction.

The blast effect on structures is very much like that of a blow of a gigantic force. Reaching a structure the pressure wave produces either destructive or pressurized effects. Pressed by the wave a light building will probably be destroyed rather than shifted while a heavier one will be shifted rather than destroyed.

The ability of a building to withstand blast depends primarily on its strength and, to a lesser degree, on its shape and on the number of openings which can serve to relieve the pressure on the outside walls. The strength is determined mainly by the type of construction. The effect of shape is not very marked since most buildings are rectangular in form. A long, narrow structure will be more resistant to blast striking it on the narrow end than on the side. However, if struck on the side, a rectangular building would probably suffer more damage than a square one.

The effect of shape is more evident in such structures as smoke-stacks. Pressures equalize rapidly around them, which makes them surprisingly resistant to blast. They often remain standing when adjoining structures are leveled to the ground. On the other hand, flat surfaces such as windows and doors in an extensive wall, will tend to give way very easily. Reinforced concrete and heavy steel-frame buildings resist the blast best. Heavily constructed

masonry buildings stand up well, but light masonry and brick structures offer little resistance and debris, including glass splinters, from such buildings become missiles which could injure persons in the vicinity. Wooden buildings offer the least resistance and will either collapse quickly or, if beyond the zone of severe destruction, will suffer damage to roofs, wall panels, and interior partitions. Permanent bridges are generally resistant to blast while the makeshaft ones are easily destroyed. Blast causes no damage to highways, railroads or landing strips unless produced by an air or underground burst in the immediate vicinity.

Tanks are little affected by blast and in fact heavy and medium ones provide good protection. Heavy artillery pieces are much less resistant than tanks; however their chances of withstanding a blast are good.

MT vehicles suffer badly both from blast and flying debris. The same applies to fragile electric and electronic equipment. Field dumps of all types will be destroyed unless dug in deeply and carefully.

Aircraft are designed to withstand great stresses and loads experienced under actual flight conditions. Because of the nature of their mission, the smaller fighter-type planes, jet fighters in particular, are designed for high dynamic pressures and accelerations with a minimum of surface area. These aircraft will be much less susceptible to blast damage than the larger aircraft such as bombers and cargo planes with their greater surface area.

Heat and fire are another cause of damage to structures and equipment resulting from the explosion of a nuclear weapon. The thermal radiation accompanying an air burst effects everything within several miles that is not shielded. The range of destruction will depend on the weapon yield and atmospheric conditions.

Because of these high temperatures, many substances will scorch, char, or even burst into flame. The actual effect will depend on the color and nature of the material and the amount of radiant heat received. Typical materials which are easily charred or burned are paper, wood, cloth, rubber, paint, and asphalt. Dark colored or dark painted materials absorb a larger proportion of the thermal radia-

tion and so will char or burn more easily than those having light color. The extent of the damage depends on the nature and color of the material. Textiles of various kinds are sensitive: nylon melts fairly easily; other fibers burn. Cotton materials, in particular, seem to be relatively resistant to heat. Loosely gathered materials, such as piles of paper or rags, thin black draperies and curtains, and canvas tarpaulins may be set afire by the radiant heat from the bomb. Dry vegetation, such as dry grass or stubble, may also be ignited.

Material which is shielded from the blast by a transparent substance, such as glass, may catch fire and may well continue to burn, for the heat will pass through the glass, but the wind may not.

Fires accompanying an atomic explosion may be classed as primary or secondary, according to their origin. Primary fires are those caused directly by the thermal radiation igniting such materials as paper, thin cloth, rags, wood, and dry vegetation. Secondary fires are due to other causes, for which the blast is mainly responsible, such as upset stoves and furnaces, broken gas and other fuel lines, and electrical short circuits.

When a large area is burning simultaneously, the phenomenon known as "fire storm" may develop. As a result of the huge masses of hot air and gases rising from the fire, air is sucked in with great force. Strong winds consequently blow from outside toward the center of the area on fire. The effect is similar to the draft that sucks up a chimney under which a fire is burning except that it is on a much larger scale.

Since the initiation and spread of fires depend on such circumstances as the type of buildings and their contents, weather conditions, and the nature of the terrain, the fire damage range will vary greatly. However, it may be expected, in general, that fire will spread to all structures which have suffered at least moderate blast or shock damage.

The damage ranges for a 20 kiloton (20,000 tons) and a 1 megaton (one million tons) typical air burst are given below.

Degrees and Ranges of Damage

Miles from Ground Zero	20-KT Air Burst	Miles from Ground Zero	1-MT Air Burst
	Light damage to window frames and doors; moderate plaster damage out to about 4 miles; glass breakage possible out to 8 miles.	10—	Light damage to window frames and doors; moderate plaster damage out to about 15 miles; glass breakage possible out to 30 miles.
2.6—	Oil storage tanks, filled: slight damage.		Oil storage tanks, filled: slight damage.
2.4—			
2.2—		9—	Fine kindling fuels: ignited.
2.0—	Wood frame houses: moderate damage.	8—	
1.8—	Fine kindling fuels: ignited. Radio and TV transmitting towers: slight damage. Smokestacks: slight damage.		Wood frame houses: moderate damage. Radio and TV transmitting towers: slight damage.
		7—	Smokestacks: slight damage.
		6—	
1.6—	Light steel frame industrial buildings, light walls: moderate damage. Wood frame houses: severe damage.		Light steel frame industrial buildings, light walls: moderate damage.
1.4—	Motor vehicles: slight damage. Radio and TV transmitting towers: moderate damage.		Motor vehicles: slight damage. Radio and TV transmitting towers: moderate damage. Wood frame houses: severe damage.
1.2—	Medium steel frame industrial buildings, light walls: moderate damage. Telephone and power lines: limit of significant damage. Wood frame houses: destroyed. Highway and R. R. truss bridges: slight damage.	5—	Medium steel frame industrial buildings, light walls: moderate damage. Telephone and power lines: limit of significant damage.

Continued

Miles from Ground Zero	20-KT Air Burst	Miles from Ground Zero	1-MT Air Burst
	Wall bearing, brick (apartment house type) buildings: moderate damage.		Highway and R. R. truss bridges: slight damage. Steel frame, light walls (office type), buildings: moderate damage.
1.0—	Steel frame, light walls (office type) buildings, moderate damage.	4—	Wood frame houses: destroyed.
	Reinforced concrete frame and walls, multistory structures: moderate damage.		Wall bearing, brick (apartment house type) buildings: moderate damage.
	Wall bearing, brick (apartment house type) buildings: severe damage.		Reinforced concrete frame and walls, multistory structures: moderate damage.
0.8—	Reinforced concrete frame building, light walls: moderate damage.		Wall bearing, brick (apartment house type) buildings: severe damage.
	Highway and R. R. truss bridges: moderate damage.		Reinforced concrete frame buildings, light walls: moderate damage.
	Medium steel frame industrial buildings, light walls: severe damage.	3—	Highway and R. R. truss bridges: moderate damage.
	Reinforced concrete frame and walls, multistory structures: severe damage.		Medium steel frame industrial buildings, light walls: severe damage.
0.6—	Massive wall bearing, multistory structures: moderate damage.		Reinforced concrete frame and walls, multistory structures: severe damage.
	Motor vehicles: moderate damage.		Massive wall bearing, multistory structures: moderate damage.
	Steel frame, light walls (office type), buildings: severe damage. Oil storage tanks, filled: severe damage.	2—	Steel frame, light walls (office type), buildings: severe damage. Motor vehicles: moderate damage.
			Oil storage tanks, filled: severe damage.

Miles from round Zero	20-KT Air Burst	Miles from Ground Zero	1-MT Air Burst
0.4—	Motor vehicles: severe damage.		Motor vehicles: severe damage.
	Reinforced concrete, blast resistant, windowless structures: moderate damage.	1—	
	All other (above ground) structures: severely damaged or destroyed.		Reinforced concrete, blast resistant, windowless structures: moderate damage.
0.3—0.2	Tanks and heavy artillery: severe damage.		All other (above ground) structures: severely damaged or destroyed.
0—	Ground zero for 20-kiloton air burst.	0—	Ground zero for 1-megaton air burst.

In zones of heavy damage, the fuel tanks of vehicles may rupture and the ignition of the gasoline may cause much fire damage. Thermal radiation may cause superficial damage to tires, paint and upholstery, but it will not ignite gasoline unless the tank is ruptured.

Nuclear radiations do not affect most materials in any visible manner. Thus the essential value of any equipment (tank, vehicle, electronic equipment) is not impaired by this effect. Radioactive contamination may be a danger to operating personnel, however.

The degree to which a particular material or object will become contaminated depends on many variables that cannot be predicted in advance. Nevertheless, two factors have an important bearing on the problems of contamination and decontamination. First, a material with a rough finish is more susceptible to contamination than a smooth one because the rough finish will give the particles more surface area to which they can stick. Second, if the material is porous, the radioactive particles can penetrate under the surface and thus become difficult to remove.

Well-painted surfaces are smooth and non-porous and consequently are less susceptible to contamination. If the painted surface is worn or weathered, however, it becomes relatively rough and porous and radioactive particles can

then penetrate more deeply into the material. Similarly, clean, smooth metal surfaces are not easily contaminated, but metals are likely to corrode and the corroded parts collect the contamination. Thus, rusty spots on metals, places where paint is chipped, cracked or roughened, and worn surfaces of wood are all areas which will become contaminated. Articles made of porous materials, such as manila line, nets and canvas, are especially susceptible to contamination.

Concrete, unglazed brick, unpainted wood and asphalt are porous, and buildings or roads constructed of these materials are very susceptible to contamination. Weathering and wearing will make it even easier for the particles to stick to these surfaces.

Listed below are approximate doses of neutrons and gamma rays, given at 1/2 mile intervals from a 1-megaton burst.

Distance	Neutron	Gamma
2.0 mi	0.5 rad[1]	40 r[1]
1.5 mi	20 rad	500 r
1.0 mi	1,800 rad	10,000 r
0.5 mi	330,000 rad	200,000 r

RADIO AND RADAR EFFECTS

A nuclear explosion is accompanied by two principal types of electromagnetic effects. These are entirely different from each other in nature, but both involve the whole spectral region of wave length longer than infrared, i. e., from about 1 millimeter on up to very large values. One type of effect involves the actual emission of an electromagnetic pulse of short duration from the explosion itself (or from the disturbed region in its vicinity), whereas the other, through alterations to the electrical properties of the atmosphere, can result in serious disturbance of electromagnetic waves, such as are used in communications and for radar, passing in the vicinity of the nuclear detonation. This disturbance may be caused by debris or water vapour introduced into the atmosphere by the burst, or by the unusual conditions created by the ionizing radia-

[1] rad, r (roentgen) see p. 151.

tions from the exploding device. The latter mechanism may cause some radio and radar systems to be "blacked out" for several hours following the explosion.

The electromagnetic pulse or "radioflash" which is produced at the time of a nuclear explosion is due to at least two different mechanisms. The first is associated with the creation by radiations from the burst of some kind of asymmetry in the electric charge distribution in the region surrounding the detonation; the second is the result of the rapid expansion of the essentially perfectly-conducting plasma of weapon residues in the earth's magnetic field. The first mechanism is often called the "compton-electron model," while the other is called the "field displacement model."

As stated above in addition to the emission of an electromagnetic pulse there developes another principal type of electromagnetic effect, which is called the atmospheric ionization phenomenon. Ionization, i. e., the formation of ion pairs consisting of separated electrons and positive ions can be produced either directly or indirectly by the gamma rays and neutrons of the initial nuclear radiation, by the beta particles and gamma rays of the residual nuclear radiation and also by the X-rays and even the ultraviolet light present in the primary thermal radiation. Hence after a nuclear explosion, the density of electrons in the atmosphere in the vicinity is greatly increased. These electrons can affect electromagnetic (radio and radar) signals in at least two ways. First, under suitable conditions, they can remove energy from the wave and thus attenuate the signal; second, a wave front traveling from one region into another in which the electron density is different will be refracted, i. e., it's direction of propagation will be changed. It is evident, therefore, that the ionized regions of the atmosphere created by a nuclear explosion can influence the behavior of communications or radar signals whose transmission paths encounter these regions.

The effects on radio communications systems of the atmospheric ionization produced by nuclear explosions at various altitudes depend on the type of system and on the particular manner in which the ionosphere is involved in transmitting the signals. The latter is determined, in turn, by the operating frequency of the system.

The additional ionization of the atmosphere will not cause any serious attenuation of the signals in the very-low-frequency range (VLF), i. e., in the 3—30 kc range. But when the ionosphere is disturbed there will be a sudden phase-shift of the signal.

A high-altitude nuclear burst which changes the conditions in the ionosphere might have drastic effect on the sky-wave transmission in the low- and medium-frequency ranges (LF and MF), i. e., frequencies from 30 kc to 3 Mc. The normally used ground wave mode of the LF and MF will not experience any appreciable influence.

Megaton-range detonations above 10 miles will cause instantaneous disruption of high-frequency (HF) signals, i. e., signals in the 3—30 Mc range passing close to the burst point.

No net changes are expected in the signals of the very-high-frequency range (VHF), that is 30—300 Mc.

Frequencies in the ultra-high-frequency range (UHF) — 300 Mc — 3 KMc and above are little affected by the electron densities.

Radar systems are similar to radio communications systems in the respect that a transmitter and receiver of electromagnetic waves are used. Frequencies normally employed in this connection are in the VHF range and above. There is little effect on signals of these frequencies so long as both the radar and the target are below the ionosphere. If the signal must pass through the ionosphere interference from nuclear detonations becomes important radar signals traversing the ionosphere will, like radio signals, be subject to attenuation. If radars are designed to detect targets at the greatest possible range even the smallest additional signal loss results directly in shortening of the range at which the given target can be detected.

Section V

EFFECTS OF NUCLEAR EXPLOSION ON PERSONNEL

The injuries to personnel resulting from a nuclear explosion may be divided into three broad classes:

1. Blast and shock injuries.
2. Burns.

3. Nuclear radiation effects.

Apart from the nuclear radiation effects, most of the injuries suffered in a nuclear explosion will not differ greatly in character from those caused by ordinary high explosive and incendiary bombs. An important aspect of injuries in nuclear explosions is the "combined effects;" that is, a combination of all three types of injuries. For example, a person not too far from ground zero may suffer from blast injury, from burns, and also from the effects of nuclear radiation. In this respect, radiation injury may be a complicating factor, since it is combined with injuries due to other sources.

BLAST AND SHOCK WAVE INJURIES

Injuries caused by blast can be divided into:

1. Primary (or direct) blast injuries, and
2. Secondary (or indirect) blast or mechanical injuries.

Primary blast injuries are those which result from the direct action of the air shock wave on the human body. It is believed that a 20-KT atomic bomb detonation will cause relatively few primary blast injuries. The greater power of nuclear weapons yielding over 100 KT and the H-bombs with a yield of several megatons will cause primary blast injuries to a large number of unprotected personnel.

Secondary blast injuries are caused mainly by collapsing buildings, and by timber and other debris flung about by the blast. Persons may also be hurled against stationary objects or thrown to the ground by the high winds accompanying the explosion. The injuries sustained are thus similar to those due to a mechanical accident: bruises, concussions, cuts, fractures, and internal injuries.

Hemorrhage and shock are frequently serious complications of blast injuries. The importance of shock cannot be overemphasized, since it is often the main factor in determining the fate of the patient suffering "mechanical" injury. Consequently, the earliest possible attention should be given to treatment for shock. Simple first aid measures are of great value.

A nuclear explosion does not present anything especially new in respect to the types of blast injuries. Both

primary and secondary blast injuries have occurred with ordinary high explosive attacks. However, with the nuclear explosion there will be an enormous number of injuries occurring in a limited area in a very short time.

BURN INJURIES

Burns due to a nuclear explosion can also be divided into two classes; that is, (1) primary burns, which are a direct result of the thermal radiation from the bomb; and (2) secondary burns, which are the result of fires caused by the explosion. From the point of view of their effects on the body and of their treatment, both types of burns appear to be similar to each other and to burns produced in various other ways.

Burns are generally classified according to their severity, in terms of the degree (or depth) of the injury. The three classes of burns and some of their characteristics are as follows:

Class of burns	Characteristics	Examples
First degree burns	Redness of skin; heal without treatment; leave no scars	Mild sunburn
Second degree burns	Deeper; more severe; blisters; slower to heal; leave no scars	Severe sunburn with blistering
Third degree burns	Injury extends through the skin to deeper tissues; heal slowly; may leave scars	Contact of skin with hot stove for few seconds

The depth of a burn is not the only factor in determining its severity. The extent of the area of the skin which has been affected is also important. Thus, a first degree burn involving the entire body may be much more serious than a third degree burn at one spot.

As with mechanical injuries, shock is commonly associated with extensive burns. In many instances the occurrence and treatment of shock are important in determining whether the injured person will recover or not. Burns are

also subject to infection, and this may have serious consequences. A late and serious complication of extensive burns is anemia.

The range of secondary burns will correspond approximately to the distance to which fires have spread. In a built-up area this will be about the same as that for mechanical destruction. The proportion of severe burns among persons who survive will be greater the nearer they are to the center of the explosion.

Flash burns are likely to occur on a large scale as a result of a nuclear explosion in the air or on the surface. About one-third of the energy of fission appears as thermal radiation or radiant heat, and most of it is given off during the first second after the explosion. The high temperatures of the skin produced by this radiation result in burns of exposed personnel. These are called primary burns or flash burns. Since thermal radiation travels in straight lines, it burns primarily on the side facing the explosion and also produces shadow effects, like sunlight.

Temporary blindness resulting from the intense flash of light from a nuclear explosion may occur. Usually, this blindness will not last more than half an hour, unless the retina of the eye is injured.

NUCLEAR RADIATION INJURIES

The injurious effects of nuclear radiations from a nuclear explosion represent a phenomenon which is completely absent from conventional explosions.

The harmful effects of nuclear radiations appear to be caused by the ionization produced in the cells composing living tissue. As a result of ionization some of the constituents, which are essential to the normal functioning of the cells are altered or destroyed. In addition the products formed may act as poisons. Among the observed consequences of the action of ionizing radiation on cells are breaking of chromosomes, swelling of the nucleus and of the entire cell, increase in viscosity of the cell fluid and destruction of cells. In addition the process of cell division (or "mitosis") is delayed by exposure to radiation so the normal cell replacement occurring in the living organism is inhibited.

The degree of the injurious effects of nuclear radiation

on biological systems is determined by the absorbed dose of nuclear radiation. A unit of the absorbed radiation is called "rad." The rad is defined as the absorbed dose of any nuclear radiation which is accompanied by the liberation of 100 ergs of energy per gram of absorbing material. The difference between the rad and the roentgen is that the roentgen is a measure of radiation exposure dose while rad is a measure of the absorbed dose. The rad is a convenient unit for expressing energy absorption but it does not take into account the biological effect of the particular nuclear radiation absorbed so another unit, known as "rem" was introduced. Rem is an abbreviation of "roentgen equivalent mammal (or man)" and provides an indication of the extent of biological injury (of a given type) that would result from the absorption of nuclear radiation.

A table defining various units of measurement of nuclear radiation exposures and their conversion factors is given below to facilitate analysis and calculations:

1) Definitions:

Roentgen (r) — unit of measure of gamma radiation — releases 87 ergs/gram of air (exposure dose).

REM — roentgen equivalent mammal (absorbed) — biological measure.

REP — roentgen equivalent physical (absorbed) — 97 ergs/grams of substance.

RAD — absorbed dose, any radiation which is accompanied by liberation of 100 ergs/gram of absorbing material.

NVT or n/cm^2 — neutron per square centimeter, exposure.

2) Conversion factors:

1 r = 87 rad

1 rep = 97 rad

1 nvt = 2.3×10^{-9} rad.

The available summary of the effects of various whole body dose ranges of ionizing radiation on human beings presents the following picture.

Below 100 rems the response is almost completely subclinical, that is to say there is no sickness requiring special attention.

Between 100 and 1,000 rems is the range in which therapy will be successful at the lower end and may be successful at the upper end.

Beyond 1,000 rems the prospects of recovery are poor and therapy may be restricted to palliative measures.

For whole-body exposures from 100 to 200 rems, hospitalization is generally not required, but above 200 rems admission to the hospital is necessary. Up to 600 rems there is reasonable confidence in appropriate therapy. For doses in excess of this amount there is considerable uncertainty in response.

The earliest symptoms of radiation injury are vomiting accompanied by nausea, loss of appetite and fatigue. The time which elapses between the exposure and the first symptoms of vomiting is called the delay time. Its length will depend upon the amount of rems received. It has been established experimentally that after receipt of a dose of 100 rems about 5% of those injured will show incidence of vomiting. If the dose is 200 incidence of vomiting will come up to 50% while the delay time is 3 hours. The dose exceeding 300 rems will cause 100% incidents of vomiting within 2 hours. The delay time is reduced to 1 hour if the dose exceeds 600 rems.

Section VI

EFFECTS OF NUCLEAR EXPLOSION IN SUBKILOTON RANGE

In the preceding chapters we have reviewed the effects of nuclear explosions produced by the 20-KT and the 1-MT devices. Tactical requirements (see Part III of this book) gave rise to the development of weapons which are capable of producing explosions in the subkiloton range. The subkiloton range explosion, i. e., the explosion with the energy release equivalent to less than 1,000 tons, has a number of special features which determine the character of its effects.

With the parameters of a 100-KT explosion as a starting-off point the following overall observations can be made.

Ranges of damage from thermal radiation in a 100-KT explosion exceed materially those from nuclear radiation (6 kms to 1.5 kms). In a 1-KT explosion the ranges of thermal and nuclear radiations are almost identical (around 8 kms). A subkiloton explosion is characterized by

ranges of nuclear radiation far greater than those of the thermal radiation. Thus in an explosion with the energy release equivalent to 1 ton the ranges of nuclear radiation exceed those of thermal radiation at the ratio of 8 to 1. In other words the area in which the personnel will be exposed to the radiation dose of 200 rems will be 65 times greater than the area where it will be exposed to second degree burns. The conclusion is obvious: the main damaging effect of a subkiloton range explosion is caused by nuclear radiation.

It has already been stated that nuclear radiation consists chiefly of neutrons and gamma rays. The proportion of these in the summary dose of 200 rems varies with the distance from ground zero and the weapons yield. With the explosion of 200-KT weapon the summary dose of 200 rems will comprise practically of gamma rays only, the neutrons being attenuated by the air. Decrease in the weapons yield is in the inverse proportion to the amount of neutrons in the summary dose. General calculations show that in a subkiloton explosion at least 60—70% of the 200 rem summary dose will consist of neutrons. The second characteristic feature of the subkiloton explosion therefore is the fact that the harmful effect of nuclear radiation will be produced almost entirely by the neutrons.

The rate of attenuation of neutrons by the air limits the distance they can travel which, in turn, reduces the hazards of atomic fires to friendly troops. On the other hand, the intense output of neutrons increases the amount of induced radiation increasing the radioactive contamination in the explosion area. Induced radioactivity in materials containing sodium, aluminum, and cobalt limits the use of military constructions and equipment affected by the explosion. Additional difficulties for the troop movement will be caused by the induced radiation of the sodium and silicium salts contained in the soil. Decontamination of the surfaces affected by induced radiation is practically impossible.

As it is the case with the kiloton and megaton explosions, the effects of the explosion in the subkiloton range depend on the height of the burst. It has been established that a 20-meter burst for the ten-ton weapon and a 10-meter burst for the one-ton weapon will give the greatest neutron "coverage." The lower the burst is the greater

will be the radioactive contamination of the soil, since the induced radioactivity will be supplemented by the radioactive fallout of the unfissioned particles of plutonium. This additional hazard is particularly unpleasant for plutonium has the half life of 24,000 years and is an active emitter of alpha particles capable of infiltrating organism with food or water.

Section VII

RADIAC INSTRUMENTS

Since nuclear radiation cannot be detected by any of the five senses, special instruments and devices have been developed to do this job. From the military standpoint, we not only need to detect radioactivity, but we need to know where the radiation is and how much. For these purposes we have radiac instruments. Radiac is the short term for radioactivity detection, identification, and computation. Radiac instruments are designed to detect alpha, beta, gamma, and neutron radiation, to measure the extent and intensity of contamination, to provide means for calculating the length of time that contamination will exist in an area, and to protect personnel by providing means for determining the radiation dose they receive.

Basically, radiac equipment developed to date operates on one of three principles: gas ionization; internal physical change, as occurs in a specially prepared phosphor glass badge; and chemical change, as occurs with the darkening of photographic film.

In gas ionization, the radiation enters a gas chamber and creates charged atoms which give up their charges as they reach the plates of the gas container, thus causing a small electric current to flow. The amount of current is proportional to the amount of radiation. By amplifying it electronically, we can measure this current and read the amount of radiation in roentgens or milliroentgens (a milliroentgen is 1/1000 of a roentgen) on a meter.

The phosphor glass detection device is one which uses the principle of internal physical change. The phosphor glass is especially prepared so that exposure to gamma radiation produces changes in its internal structure. The glass is examined by certain special wave lengths of light

which cause the glass to glow if it has been exposed to radiation. The phosphorescence is picked up with a photocell and, through an amplifier, is made to indicate the radiation exposure of the glass on a meter calibrated in roentgens. The special light source, photocell, meter and other items required for reading the phosphor glass are contained in a separate device called a "computer indicator." This principle is used to record an overall operation dose. Phosphor glass, like photographic film, shows the total accumulated dose. It may be used as a permanent record of an individual's exposure to radiation.

Photographic film, which is like the film used in a camera, is affected by radiation. The degree of darkening of the film, which is also the degree of exposure to radiation, is determined by an instrument with a photocell called a densitometer. This is the principle of operation of the film badges used for health protection in laboratories and in atomic field tests. The film measures only the total accumulated radiation dose, and once developed it cannot be used again.

There are several different types of radiac instruments used by the US Armed Forces. A number of these use the same basic principle of gas ionization. This group includes the ion-chamber survey meter, the Geiger-Müller (Geiger) survey meter, and the pocket dosimeter. Survey meters are actually dose-rate meters; that is, they show how "hot" the area is (intensity of radiation) in roentgens or milliroentgens per hour. Dosimeters measure the total dose of nuclear radiation received over a period of time in roentgens or milliroentgens. A dose-rate meter and a dosimeter may be compared to the two functions of an automobile speedometer; the dose-rate meter is similar to the needle which tells the speed of the automobile in miles per hour; the dosimeter is similar to the mileage indicator which tells how many total miles one has traveled.

Geiger-Müller survey meters are often called Geiger counters. The detecting part of the Geiger counter is the Geiger tube. This is a cylindrical gas-filled tube with a conducting coating (cathode) on the inside of the tube wall and a fine metal wire (anode), insulated from the cathode, running down the center of the tube. The cathode is attached to the negative pole and the anode to the positive pole of a high-voltage source (battery). Geiger co-

unters require 700 to 1,000 volts instead of the 100 volts used for the ion-chamber type of instruments. When nuclear radiation enters the tube, ions are produced in the gas. Because of the high voltage, the negative ions move rapidly toward the wire. If the voltage is sufficiently high, these fast-moving electrons act like nuclear radiations and are able to produce more ions in the gas. The negative ions so formed are, in turn, accelerated by the high voltage and they produce still more ions, and so on.

Under proper conditions, a single pair of ions formed in the Geiger tube by nuclear radiation will result in what is called an ionization "avalanche." Each "avalanche" is equivalent to a large pulse of current through the tube and this, with little amplification, can be made to show on a meter or be heard in earphones. Instruments operating in the high-voltage region actually count these current pulses as they occur, and for this reason are called Geiger "counters." The rate at which the pulses form is a measure of the intensity of the radiation. The pulse rate can be read on a meter, or if it is of very low intensity, can be determined by the "clicks" in an earphone.

The Geiger detector like the ion-chamber instrument, can be used for gamma and beta radiation. Frequently the tube is enclosed in a probe connected to the counter itself by a cable, and has a sliding beta shield. When the shield is in position, the thin window is covered and only gamma radiation can enter the counter. With the shield retracted, beta particles, in addition to gamma radiation, can be detected and measured.

The pocket dosimeter is actually a very simple form of ion chamber, for its action depends on the production of ions by the nuclear radiations. However, it has no batteries, and there is no flow of current. There are two forms of dosimeters; one that can be read by the individual (self-reading type); and one that requires associated equipment to read it (non-self-reading type). The non-self-reading form is often referred to as a "pocket chamber," while the term "pocket dosimeter" is used to refer to the self-reading type. Both of them are about the size of a fountain pen and appear and are worn pretty much like one.

The non-self-reading dosimeter consists of an outer cylinder made of plastic material and coated on the inside

with graphite to make it an electrical conductor. A stout wire, or an inner cylinder supported at the ends by insulators, runs through the outer cylinder. To use this instrument, it first must be given an electrical charge. This is done by inserting a charger between the outer shell and the central wire of the chamber. The chamber is then removed from the charger. If the insulation is satisfactory the charge will remain unchanged.

When radiation enters the chamber of the dosimeter it produces positive and negative ions in the gas. These are attracted to the charged wire and shell, respectively. However, since the battery has been disconnected, there is no flow of current. Instead the charge in the chamber is reduced. The decrease in the charge is proportional to the total amount (or dose) of radiation that has entered the chamber. At the end of an exposure, the remaining charge is measured and the radiation dose can be determined.

A "charger-reader" for charging a pocket chamber, and for reading the charge before and after exposure, contains a voltage source and a meter calibrated in roentgens. One charger-reader can be used to charge and read many pocket chambers.

When you are operating in a contaminated area, it may be necessary to know the radiation dose immediately. For this purpose the self-reading pocket dosimeter is used. Like the non-self-reading pocket chamber it consists of an ion chamber. To a short, central wire is attached a thin, flexible quartz fiber. This quartz fiber serves as an indicator, and its position on a scale on the inside of the dosimeter tells the dose in roentgens. A lens fitting into the end of the cylinder magnifies the scale and the fiber to make them easier to read.

To prepare the self-reading dosimeter for operation, it is placed in a charger; this provides an adjustable voltage source which is applied between the central wire and the shell. Since the quartz fiber and the fixed central wire are attached, they will receive the same charge. As a result, when the dosimeter is charged, the movable fiber is repelled from the fixed wire. By proper adjustment of the voltage applied by the charger, the fiber can be set exactly on the zero line of the scale. When nuclear radiation enters the chamber, ions are produced and attracted

to the wire and the shell. The charge is thus reduced, and the fiber moves across the scale because it is not as greatly repelled from the fixed wire as it was previously. By holding the dosimeter up to the light and looking through the lens, you can read the radiation dose received at any time.

The self-reading dosimeter does not need the associated equipment for reading the exposure that the non-self-reading dosimeter requires, but it does need a charging and adjusting device to set the fiber on zero of the scale before you use it. Again, one such charger can serve many dosimeters.

Section VIII

INDIVIDUAL AND COLLECTIVE ATOMIC DEFENSE

In the preceding sections of this book the destructive effects of nuclear weapons have been described and discussed. These effects include damage to structures and injury to personnel caused by air blast, ground and water shock, thermal radiations, and initial and residual nuclear radiations. In the present section an attempt will be made to state some of the many considerations involved in planning countermeasures against these various effects. The problem of protection is a complex one, since it involves not only the effects themselves, but also methods and efficiency of the systems for providing warning of an impending attack.

PROTECTION AGAINST BLAST

Blast will not kill directly, yet protection against blast will probably be the greatest problem. Flying debris, impelled to missile speed by the force of the blast, will convert a quiet woods or a stony field into a killing area. Shelter behind a tree may give protection against thermal radiation, but the tree may be blown down onto the individual. The force of the blast may lift the individual and throw him bodily against an obstacle. The best answer, as before, is the foxhole or other underground shelter. Again an overhead cover is desirable, since the blast wave can penetrate into the open foxhole. However, the cover must

be constructed so that it will not be crushed down onto the individual seeking its protection.

If the individual is in the open, he should "hit" the ground and seek cover if he observes an atomic detonation. The blast wave travels at approximately 5,000 feet a second; this will afford sufficient delay to get at least some protection from folds in the ground. A face-down attitude with the hands clasped behind the neck gives maximum protection against the flying debris. The cover should be behind something which will not be crushed by the blast and in turn crush the individual seeking protection. Armored vehicles again give some protection. However, if the blast is strong enough to turn them over, serious casualties to the occupants may occur.

Shelters will obviously play such a big part in individual protection that they bear more lengthy examination. From the standpoint of protection alone the stronger and deeper they are, the better. From the standpoint of practicality, we might say that something is better than nothing and that we will try to improve what we occupy initially. If a man stops, he should begin to dig. The first construction should be the prone shelter which will keep out some thermal and nuclear radiation, although its protection from blast and debris may not be too great.

PROTECTION AGAINST THERMAL EFFECTS

The radius of effects of the thermal radiation is the greatest, but the one easiest to cut down to manageable size. We know that heat radiation, which causes "flash burns," comes from the explosion and travels with the speed of light. We know it has little penetrating power. Our first protective measure then is to get the soldier behind some material which will stop the thermal radiation. Starting with things closest to him, we look at his clothing. The usual Army field uniform, especially the wool uniform, will give considerable protection. Lighter shades are better than darker, although they may interfere with the problem of camouflage. The uniform should be worn loosely for the same reason that the Arab wears loose garments — to furnish an insulating layer of air

which prevents transfer of the heat through the clothes to the skin. Above all, the clothing must cover the skin. Unbuttoning and rolling up sleeves in warm weather will be dangerous. Shorts will not be practical on the atomic battlefield. Special provision must be taken to shield the face and hands. Some of the worst burns in Hiroshima were to the face. A complete answer to this problem is not yet available. Areas of the face exposed can be covered by the hood type garments also used by the Arabs in their long experience in combating the sun. Creams and ointments are also under development. If they are successful, the problem of flash burns will be greatly reduced even for the soldier in the open. One other problem of thermal radiation is that, even though direct flash burns may not result, the clothing itself may catch fire and burn the wearer. Burn-resistant clothing is the answer, and is being developed.

The lack of penetrating power of thermal radiation makes it desirable to get something between the soldier and the source. Even when he is in the open, the soldier, consistent with his mission, should try to stay in the shade or under cover of small bushes and keep in defilade. This fortunately is coincident with his desire to take cover and concealment from enemy conventional fires. If the soldier is standing and he observes an atomic explosion near him, he should hit the ground. There is evidence that the thermal radiation while the fireball is cooling may be more damaging than that at the time of the explosion. This cooling occurs at about 3 seconds. Therefore if one can take cover immediately, at least part of the thermal radiation can be avoided.

Time permitting, there is a better way to protect against thermal radiation. That is the construction and use of shelters of which the simplest is the foxhole. Thermal radiation cannot penetrate through the sides of the foxhole, although it can of course enter through an uncovered top. However, if the foxhole is covered with a shelter-half, much of this thermal radiation will be stopped and a good defense against it will be achieved for most of the area affected by the atomic explosion. A structure with a thicker and more permanent top will give even better protection and remove the fire hazard that might result from the igniting of the shelter half.

PROTECTION AGAINST NUCLEAR RADIATION

Nuclear radiation, like heat, is initially received almost instantaneously from the explosion. Unfortunately it is more penetrating and therefore requires more positive measures. The best protection is the underground structure beginning with the foxhole and becoming more elaborate. Again we see the need for arming the soldier with a shovel or other means for rapidly preparing foxhole protection. We have already indicated the degree to which radiation causes casualties. It is preferable to keep the radiation down below 25 roentgens in one whole body dose, but 50 roentgens can be withstood without injury and even 100 roentgens would not keep the individual from continuing to fight. To learn what sort of protection we should try to achieve we must first find out how much different shieldings reduce radiation. Following is a table of protection factors showing the amount of radiation left after passing through the materials in question.

Protection Factor of Various Materials

Material	Remaining Radiation (Roentgens)
Foxholes	0.100
2 1/2-ton trucks	0.600
1/4-ton truck	0.800
Armored personnel carriers	0.250
Light tanks	0.150
Medium tanks	0.100
Concrete or timber bunkers with at least 30 inches of earth cover	0.003

These figures make it clear that it's still "mother" earth.

The bunkers, the last item on the table, while desirable, are outside the capabilities of the individual, but can be constructed as a unit effort. The table also points up the desirability for some armored protection for troops which move.

An individual in the open 1,000 yards from ground zero would receive approximately 1,000 roentgens from a 20 KT air burst. If this individual were in a foxhole, he

would receive only 100 roentgens which, as we said, was an acceptable if not desirable figure. If the individual were in a concrete or 30 inch thick reinforced earth shelter, he would receive only 3 roentgens, which would hardly be noticed in combat. The reduction power of the shelter would permit it to be placed within approximately 500 yards of ground zero without exceeding acceptable doses of radiation.

Wherever fallout occurs there is a possibility that radioactive material will enter the body through the digestive tract (due to the consumption of food and water contaminated with fission products), through the lungs (by breathing air containing fallout particles) or through wounds and abrasions. Correct use of gas masks and protective clothing is therefore of vital importance.

* * *

The individual who understands atomic effects can do much to protect himself in selecting the area in which he locates his construction or the areas through which he moves. Whenever possible heavy woods should be avoided since blown down trees and flying branches will create hazards. The woods may catch on fire even though they may reduce the danger from flash burns. Buildings are dangerous. They collapse under comparatively low blast overpressures. Foxholes should not be constructed near them. Individuals on the move should avoid towns which may be hit by atomic weapons. In addition to the crushing effects of collapsing buildings, secondary fires may occur. The individual must learn to pick up and avoid contaminated areas through use of his dosimeter or other detection device.

COLLECTIVE DEFENSE SHELTERS

Special personnel shelters are required to provide protected locations where communications, command and similar functions can be conducted without interruption from warning alerts or actual attacks.

Anything more than a foxhole with light earth cover stage, must be a unit effort, preferably with engineer assistance. The simplest strong shelter is the earth and log

bunker which is essentially our foxhole roofed over with logs and covered with 30 to 36 inches of earth. This bunker gives great protection.

With adequate time for construction, structures may become even more elaborate. Large underground shelters may be constructed behind steep slopes. They may be heavily reinforced and have thick overhead cover. They may be tunnelled into hills. Bulldozers, scrapers, and other heavy machinery should assist in their construction. The shelter will permit the men to rest and will afford more protection than bunkers. Their use will be mostly in reserve areas deep in the rear. It is conceivable that they may be used occasionally in more forward areas. In this case the shelters will be connected by trenches to bunkers on the forward slopes where the fighting will occur. These shelters will be useful to house troops in an area where heavy fallout is expected. They should be large enough to house the troops until the fallout decays sufficiently to permit the troops to leave safely.

The most elaborate construction of all is the reinforced concrete bunker or shelter, which will withstand air blast over pressures of 100 pounds per square inch. Such a structure would be concrete. A field unit will rarely occupy a concrete structure but where it can be used it should not be eliminated.

Shelters may also be designated as either first-class or second-class protection. These terms do not describe protection against blast effects, but indicate only whether air filtration is supplied.

First-class protection offers full or complete protection for personnel without masks.

Second-class protection requires that personnel wear masks for protection. First-class shelters may include facilities for personnel decontamination; second-class shelters do not.

One of the most important features of a protective shelter is its effectiveness in keeping out radioactive particles. For first-class shelters a high degree of efficiency is possible with special pressurizing equipment, which maintains a slight positive pressure within the shelter.

Another important feature of a protective shelter, and one that determines its maximum capacity, is the available air supply. Personnel engaged in light tasks will

require from 7 to 10 cubic feet of air per minute, while inactive personnel will require a minimum of one cubic foot of air per minute. Collective protectors are mechanical devices which supply first-class shelters with fresh, clean air. Air is drawn in from the outside atmosphere, purified in a canister and than delivered to the shelter room.

Section IX

DECONTAMINATION OF EQUIPMENT, LAND AREAS AND PERSONNEL

Since radioactive material cannot be destroyed, decontamination inevitably involves transfer of the source of the radiation, e. g., fallout, from a location where it is a hazard to one in which it can do little or no harm. All decontamination procedures thus have two basic aspects: first, the removal of the contaminant, and second, its disposal. Unless proper consideration is given to the latter aspect, the whole process may do little or no ultimate good. Covering the contamination without moving it, e. g., with a depth of soil, would be effectively combining both operations into one.

There are two types of decontamination which can be used for the removal of radioactive contamination: gross decontamination and detailed decontamination.

GROSS DECONTAMINATION OF EQUIPMENT

Gross decontamination is essentially a field operation in which speed is the main consideration. It will be used only in cases of military necessity. Simplest materials and equipment, even make-shift in character may have to be used, but since only temporary use of the piece of equipment or area is wantedly it will be only necessary to reduce the contamination to a point where it will not be a serious hazard to personnel.

Gross decontamination will usually be applied to such objects as vehicles, tanks, aircraft, and guns.

The addition of soap or other detergent will greatly increase the efficiency of decontamination of greasy surfaces such as you would find in vehicles. The soapless

laundry detergents are fast-acting and easily handled. Soap may be mixed with water if other detergents are not available.

The cleaning action of water with or without detergents is increased by heat. Thus, if hosing with cold water and detergent does not reduce the radiation sufficiently, hot water with a detergent should be used. Under the action of a hot water jet many grease films are melted, removed from the surface, and flushed away by the stream. Furthermore, most materials are more easily dissolved by hot water than by cold water. Detergents should be used where grease is present.

GROSS DECONTAMINATION OF LAND AREAS

Gross decontamination of land areas may be performed by bulldozers, patrol graders, or similar power equipment. Such equipment provides a certain amount of protection for the operators against the radiation from the debris. Since the use of motorized equipment may raise considerable quantities of radioactive dust, the area should be moistened with water fog. The interior of a building into which radioactive dust has entered may be roughly decontaminated by vacuum cleaning, using special filters.

After a contaminating attack, it will be necessary to clear road-ways and other access routes as rapidly as possible. This may be required for the passage of personnel and for the use of rescue and emergency teams. The quickest method for clearing a road littered with contaminated debris or of opening up a way through a contaminated land area is by means of a bulldozer.

DETAILED DECONTAMINATION OF EQUIPMENT AND PERSONNEL

As time and facilities permit, detailed decontamination is carried out, usually in rear areas or at repair bases. The main purpose is to reduce the contamination to such an extent that there would be a minimum of radiological hazard to personnel operating vehicles, and equipment for long periods of time; in other words, restoring the equipment to its original usefulness.

There are three basic methods that are used in detailed decontamination operations:

1. Surface decontamination.
2. Aging and sealing.
3. Disposal.

Surface Decontamination. — Radioactive contamination is essentially a surface condition. It can be disposed of by surface cleaning or surface removal methods.

The most practicable methods for decontaminating installations and equipment are those using:

vacuum cleaning; water; steam; detergents; complexing agents (carbonates, citrates); organic solvents (gasoline, kerosene); inorganic acids and mixtures (hydrochloric, sulfuric, acetic, citric); caustics (lye, calcium hydroxide); abrasion (scraping, grinding); flame cleaning.

Personnel Decontamination.— After an atomic explosion, it is possible that a number of individuals will become contaminated. If a supply of uncontaminated water is available every effort to achieve partial decontamination of exposed skin surfaces of these persons by vigorous scrubbing with soap and water should be made. Special attention should be paid to hair, nails, skinfolds, and any other portion of the body from which radioactive particles may be difficult to remove. Precautions to avoid abrasion (scraping) of the skin are essential.

In an emergency, if a supply of water is lacking, wiping oneself with any clean material at hand, such as paper, straw, grass, leaves, or sand, will remove some of the radioactive contamination from the skin. But the material used for wiping must be decontaminated, or it may do more harm than good.

Clothing can be partially decontaminated by vigorous shaking or brushing.

Following the preliminary or emergency decontamination, personnel will be directed by signs or guides to an improvised decontamination center.

The improvised decontamination centers will be divided into three sections: the undressing area, the washing area, and the dressing area; these centers are designed to provide detailed decontamination for personnel in the field.

PART III

NUCLEAR WEAPONS: COMBAT EMPLOYMENT AND IMPACT ON TACTICS

1 This Part contains a brief outline of the US Army views on: (a) the combat employment of nuclear weapons and (b) the impact their appearance has had on the tactics of ground units. 2 These views are based on the assumption that nuclear firepower is a form of combat power and is generally the most rapidly employable means for influencing the action. 3 Nuclear weapons may on occasion be used alone to accomplish tasks which might otherwise require a combination of fire and maneuver. 4 Plans for the employment of nuclear firepower, nonnuclear firepower and maneuver forces are integrated to provide decisive results.

5 In attack every effort must be made to increase the firepower, mobility, and communication facilities of all organizations. 6 Mobility is required to enable tactical units which are dispersed for protection against nuclear bombs to concentrate rapidly and maneuver against an enemy. 7 Communications of greater reliability and flexibility are required so that commanders may have complete control of subordinate elements over increased distances, and so that the units themselves may increase their responsiveness to command.

8 In defense, on the other hand, defending forces are to be deployed on wider frontages and in greater depth. 9 These distances will vary with the size of the unit and the enemy's nuclear capability.

10 In both the offense and defense of the future, troops will have a new awareness of intelligence. 11 To increase the

effectiveness of nuclear weapons emphasis will be placed on accurate, rapid reporting of information of both the enemy and terrain. 12 This will permit bringing all combat power to bear in the shortest possible time and under the most advantageous conditions. 13 To decrease the effectiveness of nuclear weapons of the enemy, however, all personnel must be thoroughly indoctrinated with the necessity for maintaining secrecy, effective camouflage, and the use of cover, concealment, and deception. 14 These practices will deny the enemy the opportunity to discover either location or intensions of friendly troops.

15 Dispersion, greater firepower, and mobile operations under expected fluid conditions on the battlefield will make tremendous demands upon combat support units and logistical system. 16 Artillery and engineers, for example, must have the capability of moving with the assault formations. 17 Therefore, they will be directly affected by enemy efforts, particularly nuclear, directed against frontline troops. At the same time, they must continue to provide support for these forces. These two factors will require protected mobility. The logistical system, also, must be continually improved in both organization and equipment in order that logistical support of mobile formations may proceed at a high level of efficiency. Vast quantities of supplies, great distances, and short time schedules will be the order. Air, land, and water lines of communication must be integrated, with each line of communication performing that portion of the overall effort for which it is best suited.

* * *

Effective combat employment of nuclear weapons requires that an estimate be made of the results to be expected from a nuclear attack. Usually this will include what fraction of the target area is expected to be covered by the weapon effects. Nuclear weapons are as a rule employed on a one-shot basis; even if more than one weapon is used, there is only one weapon for each desired ground zero. Unlike other fires where distribution over the target area is obtained by firing many rounds and allowing the inherent delivery errors to place the rounds randomly throughout the target area, the effects of a

nuclear weapon on the target will vary depending on the delivery errors of the single round. Consequently, it is necessary to make an estimate of the results on the target based on the relationship among the characteristics of the target, the effects of the weapon measured by its radius of damage, and the delivery errors. Such an estimate is termed "Target analysis" and is dealt with in Section VII of this part.

Section I

GENERAL INFORMATION

The effective employment of nuclear weapons requires:

— the understanding of the response of various target to the effects of these weapons; the distance at which damage or casualties may be produced; the methods of estimating the results of nuclear bursts under various conditions; and the variability of the predicted results;

— the understanding of staff procedures which enable the commander to give guidance as to the employment of allocated weapons;

— the understanding of the principles of operations in residual areas.

By way of introduction to the main matters under discussion the following concepts are defined and commented on.

DAMAGE CRITERIA AND RADIUS OF DAMAGE

Two specific types of information pertaining to the military use of nuclear weapons have been developed through weapons tests:

— the thermal, blast or nuclear radiation levels required to cause a particular degree of damage to a materiel or personnel target element;

— the distance to which the required levels will extend from a given weapon.

The nuclear weapons employment officer (NWEO) uses these data to estimate the damage that a specific weapon will cause to a target. By knowing the approximate damage each weapon will cause, he selects the most appropriate weapon for attack of the target.

Damage to materiel is classified by degrees as severe, moderate or light. These degrees of damage are described as follows:

— light damage does not prevent the immediate use of an item. Some repair by the user may be needed to make full use of the item;

— moderate damage prevents use of an item until extensive repairs are made;

— severe damage prevents use of the item permanently. Repair in this case is generally impossible or more costly than replacement.

Moderate damage is usually all that is required to deny the use of equipment. In most situation this degree of damage will be sufficient to support tactical operations. There may be situations such as the attack of fortified positions in which only severe damage will produce the desired results.

Personnel casualties (combat ineffectiveness) unlike damage, are not classified as to degree. Whenever personnel cannot perform their duties, they are considered casualties. Some personnel will be effective immediately following attack but will later become ineffective because of the delayed effects of nuclear radiation. For most tactical targets it is desirable to base target analysis on casualties rather than damage to materiel. Exceptions are targets such as missile launchers, bridges and other key structures.

The primary tool used in estimating damage to the target is referred to as the radius of damage (R_D). Generally speaking it is the distance to which a specified effect will extend. Every nuclear burst produces a radius of damage for each associated target element and degree of damage. For example, a weapon will have one radius of damage for moderate damage to wheeled vehicles, and another for casualties to protected personnel. For purposes of this discussion, all specified target elements within the radius of damage are assumed to receive the desired degree of damage.

TYPES OF BURST[1]

Nuclear weapons may be burst at any point from deep below the surface to very high in the air. Tactically nucle-

[1] For all-round description see Part II, Section III.

ar bursts are classified according to the manner in which they are employed. The terms and their associated definitions are listed below:

— subsurface burst (less than zero meters height of burst). This type of burst is used to cause damage to underground targets and structures and to cause cratering;

— impact or contract surface (zero meters height of burst). This type of burst is used to cause fallout and cratering and may be used against hard underground targets located relatively near the surface of the earth;

— low airburst. This type of burst is used for most effective coverage of the great majority of field army ground targets. As used in military publications this height of burst will preclude fallout. It is the height of burst most frequently used;

— high airburst. A high airburst is used in special cases for maximum coverage for soft ground targets, such as light frame buildings and to reduce the intensity of induced radiation in the vicinity of ground zero. However this height of burst reduces the radius of damage for most target elements;

— air defense burst. This type of burst is used against airborne target and missiles.

Section II

DEFENSE ON THE NUCLEAR BATTLEFIELD

FUNDAMENTALS OF ATOMIC DEFENSE

Defense. In a typical World War II type of defense the bulk of the units would be forward — not only the front-line elements, but also the support elements, control media and logistic installations. An atomic weapon delivered at any point along the main battle position would have produced major losses.

In a defense of the same area in the future the battlefield would be many times, as deep. Divisional sectors would be greatly increased in depth. Troop concentrations would be dramatically reduced with troops dispersed throughout the combat zone.

Such a defense in depth requires a reorganization of the battlefield and new tactical concepts. Mobility is of the

essence. Relatively small groups of all arms must be capable of a movement within the zone of action and must be able to move cross-country. 9 In this type of defense atomic weapons would not fracture the battle positions although there would be disruption and damage.

10 Defensive action will consist of "rolling with the punch." 11 There will no longer be a rigid main line of resistance. 12 The defense will be elastic; enemy penetrations of the defensive position will be normal.

13 As the momentum of the enemy is spent, the enemy forces become vulnerable to atomic weapons and are counterattacked from flanks and rear by defending battalions and highly mobile forces that are brought up from the rear.

14 To be successful these tactics demand that the Army possess the necessary means to fix the location of enemy forces and the necessary command and communications facilities to permit close coordination.

Mobile Defense. The so-called mobile defense is a defense in which minimum forces will be forward to block, canalize, delay, and disorganize the enemy, while the preponderance of the division or corps, initially in reserve, counterattacks, strongly supported by atomic weapons, to destroy enemy penetrations.

Frontages and Depths. We will start our discussion with a division defending under active atomic conditions. The first question to be determined is the frontages and depths to assign to the division.

Examinations seem to indicate that 20,000 yards plus or minus gives the best combination of dispersion and depth; the figures which, at this time, give our maximum dispersion consistent with the performance of the mission. The depth will be around 25,000 yards which should be adequate for dispersion and to give flexibility to the defender.

Forward Edge of the Battle Area. The area will be assigned to the division by lateral and rear boundaries. The forward limits of the defensive responsibility will be shown by limiting points, and at the limiting points coordination with adjacent units will be effected. In place of the old MLR (main line of resistance) we now see FEBA (forward edge of the battle area). This is not a mere change in words; it marks a revolution of defensive thought. There is no one line on which all defensive ef-

forts will be expended since it can be shattered by enemy atomics. Rather, an area will be defended. The loss of forward positions will have minor significance.

"LAYER" DEFENSE PRINCIPLE

The linear or "layer" formation appears to be the least vulnerable to atomic attack. The defender will organize within his division area a series of lines or layers, one behind the other. Each will be held comparatively lightly; each will be separated from the others far enough to insure that an atomic attack against one layer will not damage the others; but they will be close enough together so that they can be controlled and thus work together to canalize, harass, and slow down the enemy until he is weak, disorganized, tired and ripe for the counterattack. The layers, however, will extend in great depth, giving the division a depth not previously available.

Forward Battle Area. The division commander assigns several battalions to garrison the forward portion of the battle area. This is the lesser portion of his force. These battalions are each assigned appropriate frontages; these frontages force them to dispose their companies generally in a linear formation between the two limiting points. The battalions need not be mutually supporting, but if sizable gaps between them do exist, the powerful armored cavalry squadron should be more than adequate to fill in the gaps and prevent all but minor infiltration of nuisance value only. Within the division sector then, the enemy encounters not a few concentrated units with big unoccupied areas between them, but a continuous band of troops few in number and disposed in a line. But this is not a thin line even though the actual number of troops may be small.

Division Reserve Area. Behind the first battalions' areas, the division commander designates areas to be organized by the battalions in reserve. Again a linear organization for these positions in depth is specified, either by limiting points or by a line graphically indicated on the map or pointed out on the ground. The second battalions organize their areas, maintaining as much dispersion between working units as possible. The organization generally duplicates that of the forward battalions.

Additional Depth. To gain even greater depth still another layer in the rear of the battle area is organized. Thus the basic plan of the division is the organization of the defense in depth, based on those atomic-reinforced layers, giving maximum depth and minimum vulnerability.

Switch Positions. Each layer can be penetrated. The defender must therefore tie in these layers, so that a penetration in one or two places will not cause the entire position to be abandoned; and so that the canalizing effect of the defense will serve to contribute not only to slowing and confusing the enemy, but also to pinning him into areas where he can be defeated by counterattack. To accomplish this, the division commander orders the preparation of switch positions. These positions will be planned to contain the enemy in areas where he will be destroyed by offensive actions, either by division or corps. These positions permit a delaying action if the enemy attack is so heavy that it is decided that he should not be decisively engaged in this particular area. Switch positions may frequently extend across division and corps boundaries; in this event their construction and use must be closely coordinated by adjacent commanders.

Security. Security forward of the battle area will assume increased importance under atomic conditions. Even the small outguard becomes a powerful force when it can call for atomic fire on a careless enemy who permits his troops to concentrate enough to become a profitable atomic target. The familiar combat outpost and general outpost may be designated by division. A new security force may also be used. This is the reconnaissance and security line. This force consolidates and replaces the combat outpost and general outpost. It is about midway in strength between them and goes out to the front on the order of 3,500 to 4,000 yards, farther forward than the combat outpost but not so far as the general outpost. It is desirable to get the security echelons out farther than at present, so that if the enemy places atomic weapons on the security force, these weapons will not affect the battle area.

ATOMIC FIRE SUPPORT PLANS

Recommendation by Unit Commanders. The terrain forward of the battle area, will have an important part in

determining when and where the enemy will be slowed and forced to concentrate into a target. The plan will be developed as a result of the recommendations of all commanders. Recommendations made by battalion and company commanders will be for close-in atomic fires — as close in as they can be placed. The controlling consideration is troop safety. As desirable as it may be from the standpoint of killing enemy to place great big weapons out to the front, it will not be practical so long as you have some of your own men killed in the process. The troop safety distance increases rapidly as the yield of the weapon is increased. For a small increase in killing power we get a very much greater troop safety radius. This forces the junior commanders, if they would have close-in support from atomic fires, to recommend low-yield weapons. The 2 KT is not destructive enough on the enemy even though it be used closer to the defenders' troops than the larger weapons. The 20 KT, although having powerful casualty producing effects, requires such a margin for troop safety that many enemy troops immediately forward of the battle area between ground zero and the friendly troop positions may survive and continue their attack. The 10 KT seems in some cases to be the best suited for close-in protective fires for this position. The figures we are using here are for illustrative purpose only; the weapons of these sizes may not exist and if they do, the effects may be different. The considerations for planning would, however, be unchanged.

The commanders of the forward battalions make as their top priority recommendations, 10-KT weapons to hit what they consider the most dangerous avenues of approach into their areas. They would not stop with this; recommendations for as many weapons would be made as might be needed; such additional recommendations would receive lower priorities. Each commander would plan 10-KT weapons on logical approaches completely across the front. In addition, plans and calculations for many 2-KT weapons would be made in the event that the enemy came so close that it became unsafe to use a 10 KT. Weapons would also be planned to cover withdrawals and to furnish atomic fires to the battalion if it should be ordered to occupy the switch positions. The subkiloton

yield weapons available should be included in the plans for use at extremely close range.

Division Plan for Atomic Fire Support. The division should concentrate on larger and deeper targets. The highest priority weapons, labeled A and B, are planned against enemy using the best avenues of approach. Large weapons are used since the depth of the targets reduces the problem of troop safety. The main controls on the size are availability, accuracy, and the potential for causing fallout. 100-KT weapons are planned; larger ones might be utilized. Weapons C and D cover assembly areas which might be utilized prior to the attack, and 100-KT weapons are planned against these areas. The size of these weapons may have to be reduced if the presence of friendly security forces introduces additional considerations of friendly troop safety. Calculations are made to place various sized weapons on such critical points as bridges, etc.

Additional high priority weapons within the battle area are planned for use against an enemy penetration, both to try to destroy the enemy by atomic fires alone, or what is more important, to support the counterattack. We must remember that the atomic defender will usually expect to defeat the enemy primarily through the offensive action of a counterattack. This is the reason why these weapons have so high a priority. Troop safety is a consideration for those weapons to be detonated immediately forward of the switch positions; for a similar reason 20-KT's rather than the larger weapons are planned. In the rear part of the penetration a 100 KT is planned; troop safety is not a factor since friendly troops are quite a distance from the planned burst.

Many other weapons would be planned by division, just as they were by the battalion. Not only would these be planned to cover all areas forward of the battle area, but there would also be many other weapons planned within the battle area. The mobile type defense envisoned makes other penetrations and deeper penetrations possible. It is likely that the enemy will have to be fought throughout the entire division battle area with corps or even army doing the counterattacking.

When all plans have been completed and coordinated, they will show ground zeros for many sizes of weapons — many more than each commander can expect to receive.

When the enemy attack comes, decisions must be made at each echelon as to which weapons will best serve the purpose of the unit — a considerable amount of selectivity will have to be exercised. Planning for atomic fire support in the defense should be complete, but a completed plan covered with DGZ's and blanketed with radii of effects should not lead the commander to believe that no other fighting is necessary. When the action occurs only a few of the planned weapons may be available; the enemy will almost certainly get some troops through, so that somewhere, possibly at company level, a non-atomic fight will take place to finally defeat the enemy.

The discussion has been based on an enemy in the open, as the attacker will frequently be, and friendly troops in foxholes. If this does not reflect the actual status, the radius of effects planned on must be changed. If, for instance, the enemy is in armored personnel carriers, the radius of effects must be reduced, so that to produce the same damage, more weapons or larger weapons must be used. If the friendly forces are in the open, as they may well be if they withdraw to an uncompleted switch position, smaller weapons must be used or the ground zeros must be moved back because of troop safety.

Section III

ATTACK ON THE NUCLEAR BATTLEFIELD

FUNDAMENTALS OF ATOMIC ATTACK

Changes in Tactics. The increased power of tactical atomic weapons and improved delivery means have allowed the attack of deeper objectives, which in turn increases the area that combat intelligence agencies must cover. Three major tasks which in the past were performed by an attacking force — locating and holding the enemy in position; maneuvering against him to gain an advantage; and at the decisive time launching an overwhelming attack against him — still hold true, though perhaps with differing emphasis. The traditional "Find," "Fix," "Fight," and "Finish" laid greatest emphasis — perhaps because it was the most difficult and costly — upon the last two. With the addition of the tremendous power of nuclear

weapons the emphasis has now changed. Much more emphasis is now placed on "Finding" and "Fixing" the enemy, so that he can be "Finished" by a nuclear weapon. The gathering of complete and reliable information of the enemy's defensive dispositions, its proper evaluation and interpretation, and prompt dissemination, are essential to the proper employment of atomic weapons tactically in the attack. Special efforts must be made to detect the location of suitable targets within the enemy defenses. Data about the nature of a target such as its location, size, shape, concentration, vulnerability, and probable duration is needed to allow the commander to property determine his course of action.

Plan of Attack. The plan of attack consists of the plan of maneuver and the plan of fire support.

Purpose of Attack. The purpose of offensive action is the destruction of the enemy's armed forces, the imposition of the commander's will on the enemy, or the seizure of territory in order to further operations. The availability of organic nuclear fire support to the division requires a re-evaluation of the classic relationship of terrain to weapons systems, tactics, organization, and objectives. Terrain continues to be important, but in a different aspect. In the past a commander's plan was often directed toward the seizure and retention of critical terrain features which would give him a decisive advantage by providing observation, cover, and concealment. Today with Army aviation providing observation for atomic artillery and missile firepower to blast located targets, such positions are no longer as important to the overall battle. This is not to say that terrain is no longer a factor to be considered. Vital areas, both strategical and tactical, must still be fought for and held. These areas will be fought for, not so much for themselves but as a means of influencing the battle by creating favorable opportunities for emplacement of tactical atomic weapons to destroy the enemy and denying similar advantages to the enemy. Depending on their level, subordinate units will generally be given somewhat different missions to accomplish this destruction of the enemy. For the division and lower units the mission generally will be translated into terms of seizing one or more terrain features which will give the friendly forces an advantage over the enemy. The idea will

be to seize the terrain features needed so the attacker can keep the enemy from moving, working, operating, firing his weapons, or what have you. It is only by offensive action that the attacker can keep the enemy off balance.

Coordination of Nuclear Firepower with Movement. The atomic weapon has given the attacker tremendous firepower with which to destroy the enemy. However, the atomic weapon will not accomplish the mission alone. To be effective, tactical nuclear weapons must be used in con-

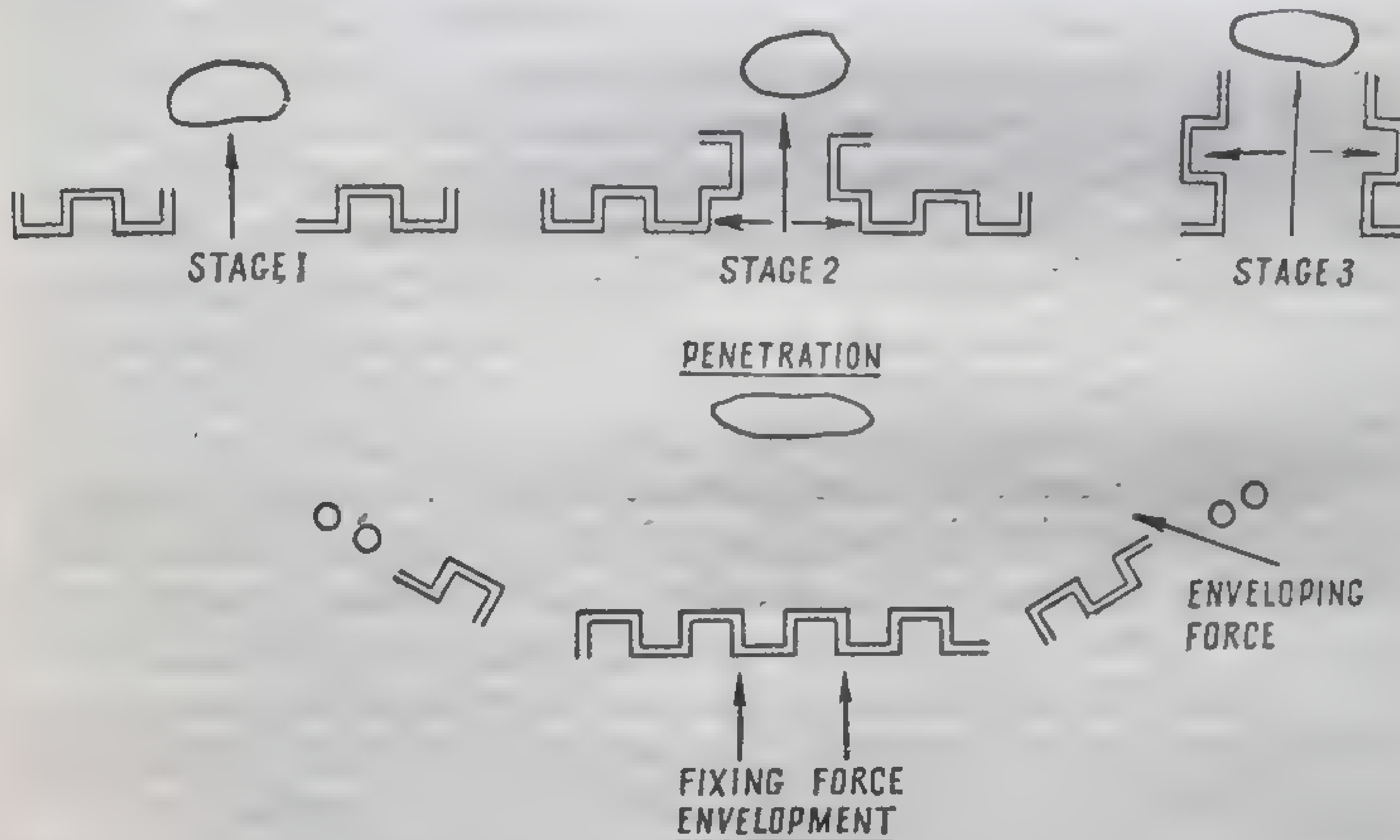

Fig. 27. Forms of maneuver.

junction with land armies. Nuclear weapons are not an end in themselves — they are a means of fire support, more powerful than any the attacker has had before, but still with the mission of assisting the commander to accomplish his mission.

Penetration (Fig. 27). The penetration is designed to break a hole through the enemy position. It normally proceeds in three phases or impulses. This does not mean that for each of these impulses there must be pause or that the three impulses cannot take place simultaneously. The impulses are:

— rupture of the enemy battle area by a force attacking on a narrow front and in considerable depth;

— widening of the gap;

— seizure of the objective.

The last two are almost always accomplished simultaneously by two different elements of the attacking force.

Envelopment. The envelopment is an attack on the defender's flank. Its main effort often is directed to pass around the defender's main position and seize an objective in his rear. Certain conditions are essential to employ an envelopment. The defender must have an assailable flank. If the attacker does not achieve surprise, he may be blocked by enemy reserves shifted to protect the flank. Deception therefore is important in the envelopment. An essential element of the envelopment is the fixing force; that is, the pressure force which attacks the enemy frontally while the main attack is going around his flank. If the attacker did not have such a force, the defender could shift his troops to meet the envelopment, so the attacker might then and by making his main attack along an undesirable approach, and with the erstwhile defending troops free to maneuver against the attacker's flank.

Penetration Vs. Envelopment Using Nuclear Weapons. A re-examination is necessary in the light of atomic weapons. Such ideas as the enemy "main position" mentioned in the envelopment have lost some of their significance. The necessity in the envelopment for wide detours, and movement over frequently undesirable terrain, may slow down the attacker, at least in the initial stages of the operation, and increase his vulnerability to atomic retaliation. The idea of a large fixing force with its immobility appears similarly undesirable. On the other hand, the possession of atomic weapons should increase the desirability of the penetration since it should simplify the blowing of a hole in the enemy position in terrain which will facilitate speed by the attacker. In atomic warfare, therefore, the relative importance of the forms of offensive action may well be reversed. Although the envelopment may be used, it may less often be the preferred way to accomplish the mission. It seems evident that the penetration by atomic supported elements, skillfully exploited to enable them to move quickly to the enemy's rear, will be used more frequently. The defender's strength will not be measured in terms of troops; weak defensive areas will not be those where troops are few but rather areas where an attacker can move rapidly. Concentrated troops and concentrated conventional firepower may indeed come to be regarded

as weakness since once located they can be so easily eliminated by atomic fires. Sufficient forces can be concentrated for an attack through mission-type orders with close coordination and planning. Battalions will remain widely separated until the last moment. The stopping in the assembly area may become obsolete — instead the attacking units will continue moving, widely separated, until near the enemy. They will either not converge at all, or converge rapidly and, once the objective is taken, disperse as rapidly as possible as protection against an enemy nuclear strike. Superior mobility and communications will be essential to live and fight in this manner on the nuclear battlefield.

TACTICAL CONTROL MEASURES

The important portions of orders to the maneuvering force in the attack are expressed by tactical control measures by which the commander organizes the battlefield and insures that his concepts are put into operation.

Objective. An objective is considered a terrain feature which must be seized and cleared of effective resistance. Let us view the selection of this objective as it might appear through the eyes of a battalion commander. Company A is located at Area X. The battalion commander wants Company A to seize Hill Y. To indicate this, the battalion commander has designated Hill Y as an objective. It cannot be bypassed. With no further controls, the company commander can take any path to the objective that strikes his fancy. The battalion commander may want to exercise more control than this. He does this through the use of additional tactical control measures designed to keep his companies in a particular area or locality so that he can better coordinate their actions.

Zone of Action. He may do this by assigning a zone of action. This tactical control measure is described by boundaries, a line of departure from which the friendly troops jump off, and an objective at the other end which they must capture. This zone of action defines the area in which the company may operate without restriction. If the zone is fairly wide and deep it is an unrestricted control measure. The zone of action without other controls is so little restrictive that it frequently will not permit the ne-

cessary control by the battalion commander or necessary coordination between adjacent companies. A unit assigned a zone may cross its zonal boundaries but only after coordination with the unit on the other side of the boundary.

Line of Departure, Time of Attack. The one control measure that is inseparable from the time of attack is the line of departure. The line of departure and the time of attack are mandatory to get things started at a time and place known to everybody. This permits the basic coordination of weapons, fires, and units when the attack starts off, which is so essential to a successful attack.

Axis of Advance. The axis of advance may be used instead of the zone of action. Usually there is a line of departure at one end and an objective at the other. A unit assigned an axis of advance may bypass defender's troops which will not interfere with the accomplishment of the attacker's mission. The attacker may bypass comparatively small forces but the bulk of the attacker's unit must be on or about the axis; deviations are not permitted. If the battalion gets an axis from division, the battalion commander may prescribe two axes astrides the original axis. An axis gives a unit adequate freedom, especially against small forces, without permitting it to wander all over the area. While allowing maximum freedom of action to his subordinate unit leaders, a commander must still know the location and situation of his units if he is to be able to react promptly with atomic fire support when needed.

Use of Control Measures. These tactical control measures may be used together. For example, there may be a zone of attack in which in addition to the final objective, there are intermediate objectives assigned. This combination of control measures is quite restrictive, since each objective assigned may not be bypassed but must be seized and cleared. It is used when movement is comparatively slow and a high degree of coordination is necessary. We may also employ both a zone and an axis of advance. This is rather uncommon; however, it may be done when the zone is very wide, or when a zone is assigned, and intermediate objectives will exercise too restrictive a control on the subordinate units.

In the past the zone with intermediate objectives was

the most commonly used control measure in an attack against a strongly dug-in defender. It permitted the commander to set up a step-by-step, closely controlled operation, whose slowness was compensated for by the coordinated fire and manpower which the commander could bring against the defender. When a series of intermediate objectives was assigned, their seizure was usually directed in a carefully planned and detailed order which of necessity took away some of the flexibility of subordinate leaders. Intermediate objectives require frequent deployments; mounted troops may have to dismount to clear the objective area. Since our intermediate objective can not be bypassed, a small enemy force may be able to delay the attacker until the enemy's atomic fires can be placed. This is a major disadvantage to the assignment of multiple intermediate objectives.

The zone of action with no other control measure, on the other hand, overdoes freedom for the subordinate units. If there is no other control, then once the companies of a battalion cross the line of departure, about all the battalion commander knows is that they will not run into each other. It would be like setting a pack of dogs after a fox; once the dogs are released, their master's control is gone and all he can do is hope they corner the fox. The battalion commander would be neglecting the primary reason for the existence of any commander, which is to coordinate the efforts of his subordinates toward a common goal; and, equally important, to know their whereabouts at all times so that he will be able to bring to bear his atomic fires when and where needed.

The axis of advance meets most of the objections to other tactical control measures in the atomic attack. It is reasonably unrestrictive, but still the battalion commander exercises sufficient control so that he can be in a position to influence the conduct of the action. The subordinate commander receives a mission-type order which does not tie down his every move, and the ability to bypass puts emphasis on speed; but he still must conform to a general pattern of action in an area reasonably well defined by his superior. The axis of advance is the tactical control measure which best expresses the spirit of the atomic offense. It can be expected that it will be used more frequently than other tactical control measures in the

attack, although limitations of terrain and equipment will present situation in which the attacker may have to use the more restrictive tactical control measures.

FORMATIONS

To succeed on the nuclear battlefield the attacker must disperse his units, the dispersion extending at least to the battalion. Mutual support between battalions is no longer figures on the basis of machinegun and rifle fire, but on the basis of mortar, artillery, and even longer range atomic fire support. An adoption of a columnar formation for the attack will make the defender's atomic strike less effective for reasons similar to those which led to the adoption of linear formations in the defense. The attacking columns move at right angles to the lines of the defender so that the fires of the attacker's atomic weapons should be concentrated forward of the attacking forces. Formations which best permit speed of movement will be emphasized, so that the defender will be furnished with only fleeting targets and so that the attacking units will arrive at their objectives in the enemy rear areas as rapidly as possible. Foot troops moving in the open do not have the mobility to use formations of this type successfully. Mechanized, lightly armored units can more readily fill the requirements. In certain situations, helicopter companies can be used to give added mobility to units at critical times and places on the battlefield. The attacker must, however, develop his tactics based on these flexible, mobile, columnar formations moved by APC, helicopter, or foot, as the situation dictates. He must be prepared, however, to modify his tactics and formations as practicable to meet new situations as they develop.

NIGHT OPERATIONS

Night offensive operations will increase over those in non-atomic warfare. Behind the area of contact this increase will be great. For the units in contact, there will also be some increase. At the company and platoon levels, night attacks will be conducted by stealth, probably without atomic support, utilizing tactics similar to those presently used. At higher echelons night attacks will take

place at the start of an offense, to achieve surprise, or to exploit successful daylight penetrations. The conduct of night operations will approach as closely as possible that of daylight operations.

ATOMIC FIRE SUPPORT PLANS

Corps Planning. The corps is expected to have approximately 24 atomic weapons of 2, 10, 20, 50, 75 and 100 KT yields. The corps atomic fire support plan is prepared by the corps G3 and the assistant G3 (Special Weapons Officer). The plan designates set targets (scheduled fires) for a number of weapons while others are retained for "on-call" and opportunity targets.

The massed scheduled atomic support is given to the division detailed for the breach of the forward enemy position and the seizure of the corps objective. The on-call atomic fires are used to support the breakthrough of the rear positions. A limited number of weapons, usually not exceeding four scheduled fires, are designated to support the flanking movement of friendly troops. The target areas for the scheduled fires are designated by letters in the order of their priority: target area Alpha, priority one (A-1), priority two (A-2), etc., target area Bravo, priority one (B-1), priority two (B-2), etc., target area Charlie, priority one (C-1), priority two (C-2), etc.

Division Fire Support Plan. The division fire support plan is prepared by the division G3 and assistant G3. In the division plan the enemy 1st defense line would be target area Alpha with priority one. Target area Bravo contains the supporting weapons and some reserves. Target area Charlie includes the located enemy reserves which could interfere with the breakthrough. Target area Delta would be atomic delivery means; target area Echo, the corps command post, and target area Foxtrot — the enemy's second defense area are designated as "on-call" targets; target area Golf (the third defense line) is another on-call target with second priority for this category of targets.

In addition to the two on-call targets cited above, many other key areas in which possible employment of atomic weapons can be foreseen, will be selected as on-

call targets to reduce to the minimum the time needed for delivery of requested atomic weapons.

All in all the division will dispose of nine scheduled fires required for target areas Alpha through Delta. Target area Echo is referred to corps.

The detailed atomic fire support plan given below may serve as an illustration.

Selection of Delivery Means. Selection of delivery means against divisional targets is made by Division G3, assistant G3 (Special Weapons Officer) and divisional artillery S3. The use of the atomic damage template will allow rapid calculations at the division level. The troops safety line is based on friendly troops in the open to warn all concerned not to be out of foxholes at the announced time for the weapons to go off (A-hour). To maintain the desired secrecy no unusual activity in the fires prior to A-hour must be shown.

The more probable selection of delivery means for the designated targets would be as follows.

Weapons A-1 through A-4 (target area Alpha) should be delivered by corps artillery to ensure maximum accuracy. Weapons B-1 through B-3 (local reserves in targets in the rear part of the defense line) are delivered by the Honest John (or Little John) guided missiles.

The mobile reserves being beyond the extreme range of the Honest John can be reached by the Corporal or the Sergeant.

Air delivery is used against enemy atomic delivery means.

Detailed Atomic Fire Support Plan

Target	WPN Yield	Description of Target
A-1 A-2	10 KT	Dug-in infantry battalion
A-3 A-4	20 KT	Dug-in infantry battalion
B-1 B-2 B-3	100 KT	Infantry reserves, artillery units and command post
C-1	100 KT	Enemy mechanized reserve
D-1	100 KT	Atomic delivery means

Section IV

UNIT PROTECTION AGAINST ATOMIC ATTACK

Unit protection is the responsibility of commanders and is devised for the unit as a whole. These protective measures may be either active or passive. Active measures are those which prevent the enemy from placing atomic weapons on friendly forces — these are usually the responsibility of commanders. They are those positive means taken to engage and destroy the enemy forces, to neutralize his weapons, and to neutralize his intelligence efforts. Passive measures are those taken to minimize loss of effectiveness of individuals and units in the event that the enemy is able to fire his atomic weapons. These measures may be either individual measures, supervised by the unit commander, or they may be measures put into effect by the unit commander.

This section will look at all aspects of protection. In order to consider this very important subject in one compact section, there may be some apparent duplications with other portions of the book. The subject of protection is so interwoven with other phases of atomic warfare that some repetition is actually profitable since it places emphasis on the methods of reducing the effectiveness of the enemy's atomic capabilities.

Unit Protection by Dispersion. Dispersion is an efficient means of unit protection against atomic attack. Measures on dispersion must be related to the combat activities of the friendly troops, to the degree of mobility they possess, to the atomic capability of the friendly troops and that of the enemy and to a variety of other questions. The measure of dispersion can only be established by analyzing each situation. The general criterion is "maximum dispersion consistent with the performance of the mission."

If a battalion is in the rear area, and it is completely mechanized and the enemy must cross obstacles to reach it, it can disperse widely, by companies, and the companies might even disperse by platoons, if the enemy atomic capability showed this would be desirable. This same battalion in the forward area with no obstacle to slow the enemy, would have much less separation between its com-

panies, and the separation between platoons would be minor.

A unit with only foot mobility would have to be more compact than one which is mechanized, smaller units would be less dispersed proportionately than larger ones; for smaller units, there would be less dispersion in the attack than in the defense, although for larger units the dispersion could be as great in the attack as in the defense.

As you move down the unit scale it becomes less and less practical to disperse more than is required for coverage of the area and defense against non-atomic weapons. At the platoon level, the formation would not change materially regardless of whether warfare was atomic or non-atomic, and the same would be even truer of the squad. Increased dispersion within these two units would add problems of control, coordination, supervision, and morale which would more than overcome any advantages that might be gained from a little additional separation.

There are times where great dispersion is practical, and conversely other times when a degree of concentration may not be too dangerous.

Each commander should constantly check his unit to see if he has dangerously concentrated it. This can be done with ease by use of the atomic damage template. Here let us assume that the division G3 has used a 75-KT template because he has indications the enemy may use this size weapon. He has found that the overall concentration in the division rear is too great. He also has found that the division mobile reserve is extremely vulnerable. There appears to be undesirable concentration in the rear battalion position and also in the right portion of the battle area. The division commander, acting on this information, will order the division mobile reserve to disperse into a greater area, and will direct that the artillery units in the area of the right rear battalion be relocated. For the division rear, he will request more area from Corps to permit the necessary dispersion. The battalion commander would make a similar analysis, using possible a 20-KT atomic damage template. The analysis should be made for attack as well as defense.

Use of Linear Formation. The adoption of a linear formation by units in contact whenever possible will greatly

reduce the vulnerability of the unit. This idea must, of course, be applied with common sense. It is not necessary for a defending platoon to follow a mathematically straight line, come hell or high water. The individual shelters of the platoon should be located with reference to the ground. They would more often than not, although generally linear, have minor irregularities, as they have in the past. Certainly we would not place a foxhole on a reverse slope just to maintain a linear arrangement.

The same is true of the company — it would accept refused flanks and platoons which are slightly offset. However, the linear formation would usually require at least 3 platoons generally aligned. To use two platoons up and one platoon back would create an ideal atomic target. When all these units are put together it will be found that the battalion is generally disposed in the desired manner. Since the battalion is the ideal target for the atomic weapon, it is at this level that the linear formation does most good. However positions will also be prepared which in case of necessity will allow for all-around defense.

In the attack, the line still gives the best protection of any formation. Sometimes the line may be a deployed one, parallel to the enemy. More often, at least at the battalion level and especially if the unit is mechanized, the line may be at right angles to the enemy, but still a line. At times the part of the battalion in contact may be deployed in a line while the remainder may be in column forming a "T." Box or circular formations should be avoided whenever possible. As we go down through the company to the platoon and squad, we find less advantage in using the linear formation. At the lowest echelons control is the most important factor — the platoon in any formation whether linear or not will cover so little ground that nuclear protection from formation will be negligible.

Protection Through Mobility. There will be great emphasis on movement on the atomic battlefield. Obviously if a soldier moves he can't take his foxhole with him. One of the great problems of atomic warfare is to bring the infantryman to where he can assault the enemy defenses or launch his counterattack without getting him killed en route.

The armored vehicle is the best answer which has been devised so far. An armored personnel carrier, while not

affording quite as much protection as a tank, reduces considerably the hazard of moving around the battlefield. They are particularly good for crossing areas contaminated with residual radiation. If the terrain permits and the vehicles are available, they should be used. If armored vehicles are used, the infantry should ride them as far forward as possible even on to the objective. One caution — this will not often be possible, and even when it is, the infantryman will have to dismount when he gets on the objective. The infantryman still fights on foot — armor just rides him safely to the area in which he must fight.

The importance of the use of helicopters to add to battlefield mobility must not be overlooked. The speed of the helicopter gives added importance to its ability to move troops on the battlefield. The combat power of a company at the right place at the right time may well be more important than the arrival of an entire division at a later time. Consideration must also be given to the ability of the helicopter to fly over heavily contaminated or blown-down areas that might otherwise call for extensive detours or even completely block movement by foot or vehicle-mounted troops.

Protection Through Use of Smoke. Thermal radiation has the potential of causing casualties to unprotected personnel at great distances from ground zero. Fortunately it has little penetrating power. In its passage through the air this heat radiation is slowed down by striking air molecules. The heavier the air, the more molecules in a given volume and the more radiation is stopped. Smoke and fog are particularly effective. The necessary smoke can be produced by chemical smoke generator units which can cover large areas. To give greater protection to troops, especially those who must be in the open, they should be wrapped in a blanket of this smoke.

Selection of Defensive Area. The unit commander can reduce casualties by properly locating his troops. In the defense under ideal conditions foxholes should be dug in firm earth free from loose rocks on the surface. Buildings should be avoided as their collapse could cause many casualties. If a strong shelter with considerable overhead protection is to be built, positions may be in woods. It must be remembered that the woods may catch on fire,

and that fallen timbers make it difficult for the unit to be reinforced. If there is only time for foxholes without strong overhead cover, woods should be avoided as they will produce many casualties from secondary effects of blast. Units in the attack should not move through woods and cities, since the debris from secondary blast and the probable fires will be dangerous to the moving troops. It must be kept in mind, however, that less than ideal conditions must frequently be accepted by lower unit commanders in order to carry out the corps of division plan.

Avoiding Contaminated Areas. Areas contaminated by residual radiation should be avoided. This may not always be possible since it is usually desirable to exploit an atomic strike, which is the area in which contamination will most often occur. If the area cannot be avoided, the commander must make every effort to have his troops move through in armored vehicles or sandbagged trucks, and to move through quickly. If troops on foot must traverse the area, a potentially dangerous operation, they should do so as quickly as possible, and should be accompanied by measuring devices to warn them instantly when areas radioactive above the acceptable risk are approached. If it becomes necessary to operate in a contaminated area, then a careful accounting must be made of the amount of radiation each soldier receives. The dosimeters are best for measuring the accumulated radiation dosage. If these are not available, a list must be maintained by the commander showing the time each soldier has been in the contaminated area. By use of proper tables, it can be determined how long he may continue to work until he reaches the maximum permissible dosage. At this time he should be withdrawn from the area and another soldier who has not yet reached the maximum acceptable dose should replace him. How much the permissible dose is for any situation is set by the commander. When the mission of the unit requires operation in contaminated areas, the commander will permit greater dosages than when this is not a consideration. If the unit must remain in a contaminated area, it may be desirable to decontaminate it. This can be done by scraping off the surface earth down to a depth where the radioactivity is no longer dangerous. It is preferably done by bulldozers, but it can be done by

men with shovels. Obviously in either case the area which can be decontaminated is not large. Care must be used in disposal of the scrapings, which will be highly radioactive. Contaminated machinery may be decontaminated from fallout by flushing with water. More serious cases may be cleaned by using chemical compounds which remove paint and greases.

Control of Number of Troops Outside Protection. Emphasis on shelters and armored vehicles will not be much good if they are not properly used. Troops must be in protected places except when their duty requires them to be out, even though this may force them into narrow foxholes or armored personnel carriers for long monotonous periods. The number who can come out when not required by combat duties should be carefully regulated by the commander. An upper limit, not over 25 per cent and preferably less, must be set.

Supervision of Key Personnel. It is vital that a standing operating procedure for key personnel be set up. A detailed SOP on the succession to the command must be established and everyone in the unit down to the last private must know it. Mass destruction of leaders must not be permitted to disorganize an otherwise combat efficient unit. The duties of key personnel require that they be in the open much of the time. Supervision must be accomplished personally; if supervision is not adequate, the unit will fall apart. Commanders must confer, reconnoiter, plan. If their actions are not carefully regulated, an atomic burst which caused few casualties to dug-in troops might knock out all the exposed leaders.

Warning System. To tie in all the passive protection measures, the unit must set up a series of warning and reporting systems. These warn of enemy air attack and they inform the command of the detonation of atomic weapons in the area and of the presence of induced radiation, fallout, fires, and obstacles. They indicate, by use of troop safety lines where danger from friendly atomic weapons may exist. Reporting systems attempt to locate and assess damages quickly so that appropriate measures can be taken to evacuate and replace casualties to personnel and equipment. These warnings and reporting systems must be tied in with an organized plan for taking care of casualties. These casualties will occur in mass. The unit aid

station must be prepared in advance. A rapid sorting method to separate the fatally injured, the seriously injured, and the lightly injured should be set up. Evacuation by helicopter should be normal. Large dressings will speed up the care of burn injuries.

Camouflage and Concealment. Concealment and cover are used to keep the enemy from observing friendly troops dispositions, either from the ground or the air. Partly wooded terrain provides excellent protection from hostile observation but may restrict friendly observation and fields of fire, and increase danger from blast damage by nuclear weapon. If the terrain is flat and open, much digging and camouflage are needed to conceal the defensive position.

Camouflage is the use of natural or artificial materials to improve the natural concealment of an object or a position. Nets and chicken wire as well as brush and other vegetation may be used. Camouflage methods include: blending (concealing the materiel or position by blending its appearance with camouflage materials so as to appear as a part of their background); hiding (concealing the identity of an object with a screen or net, even though the screening is visible); and deceiving (disguising an object so as to appear as something else, simulating military works or objects, or deceiving as to identity, strength, intensions, or degree of activity).

Counter Reconnaissance. There must be an overall plan to prevent the enemy from acquiring information, or at least the correct information, of dispositions of friendly troops. The first ingredient of this program is the counter-reconnaissance force. This consists of ground security elements which keep enemy on the ground from looking into the battle area in the defense, and an air cover to prevent enemy observation aircraft from flying over. It also means use of security codes, remote control stations, and jamming of enemy radio reception sets to keep the enemy from gaining knowledge through listening to friendly communications.

Deception. This may be accomplished in the defense by dummy positions, use of security forces to deceive him as to the true location of the battle area (this may of course be tough on the security forces) and false messages. In the attack the feint, a sort of secondary attack without a

serious mission, and demonstrations may turn the enemy's attention away from the main attack until it is too late for him to retaliate against it with atomic weapons. In both attack and defense, dummy positions can be turned into the real thing. If time permits, a dummy position can be made into a strong defense. A maze of positions in a battle area, all of which can be occupied, but few of which are occupied at any one time is a potent method of deceiving an attacker.

Movement. There must be movement in all units, both attacker and defender, both forward and rear and to the flank, if they are to continue to operate very long. These movements, even if by comparatively few individuals, can give an overall picture of the location, operations, and even the intentions of a unit.

The best method of concealing movement is to move only in periods of reduced visibility; in fog, in smoke including that created by smoke generator companies, and at night. Night will be the time of movement for units out of contact except in cases of emergency.

For the defender in quiet situations, night movement will be the rule; during active situations, movement during daylight hours will of necessity be frequent. In the offense some attacks will be made at night; probably more than heretofore. However, attacks may well continue to be conducted most often in the daytime.

For the unit which must be exposed in daylight, one of its best defenses against atomic weapons is movement. A moving unit is harder to hit, especially since there is a delay time of 15 minutes or more to engage an on-call target with an atomic weapon. The faster the unit moves, the more difficult it is to hit. Movement is one of the cornerstones of the concept of offensive and defensive tactics. Even in the defense, the idea of static forces is replaced by fluid concepts. The advantages of movement are not limited to daytime operations in forward areas. It must be accepted that the longer an area is occupied, no matter how well camouflaged and how little the daytime movement is, the enemy will eventually locate it. Therefore, rear-area units should move frequently, moving of course at night. Care must be taken that a unit vacating one area does not next occupy an area recently used by some other organization. Frequent, speedy, mo-

vement, then becomes the normal for every unit on the atomic battlefield whose mission does not demand that it be fixed.

Destruction of Enemy Atomic Weapons. The best protective measure against enemy atomic weapons, although the most difficult to implement, is the destruction of the hostile weapons and the means for delivering them. This is accomplished by offensive action — it may some day be the primary mission of all offensive action. At lower echelons the degree to which this destruction can be accomplished is limited because of the depth at which the delivery means may be located. Nevertheless the unit should contribute as much as it can. For aircraft delivered weapons, aircraft warning system can be of assistance. For weapons delivered by rocket, guided missile, or artillery shell, accurate reports of size and effect preferably as a greatly expanded "shellrep," will help to locate the origin of the weapon and permit counterbattery action against it. Prisoner reports indicating the location of delivery means are important and should be rushed to higher echelons.

When a delivery means is located it may be destroyed by counterbattery fire from artillery, rockets, missiles, or by air strikes. It may also be destroyed by raids. Raids for this purpose may be airborne, they may be by infiltrating units, or they may be made in force by armored units. The successful elimination of enemy atomic delivery means during crucial periods of operation may make the difference between success and failure.

Section V

COMMAND RESPONSIBILITIES, STAFF PROCEDURES AND TECHNIQUES OF EMPLOYMENT

The command actions and staff procedures involved in the employment of nuclear weapons are an integral part of the normal sequence of command and staff actions. The command, logistical, intelligence, and operational actions required for effective employment of nuclear weapons are carried out concurrently rather than sequentially.

To achieve economy of nuclear firepower, nonnuclear fire support is used upon appropriate targets, while

nuclear weapons are used upon those targets that require greater effects.

Commanders exercise the same thoroughness in planning the use of nuclear weapons as in the employment of their major tactical units. Co-ordination and concurrent planning of nuclear fires, nonnuclear fires, and maneuver are essential. Nuclear fires frequently will render a ground assault on the target area unnecessary as a result of damage inflicted and often impracticable as a result of obstacles created. Often the use of nuclear weapons will be the decisive element of the attack or defense. Even the threat of the use of such weapons may inhibit movement or concentration of large forces.

At a low level of nuclear weapon usage, fire and maneuver receive equal consideration by the commander in determining the appropriate combat power to be applied. At higher levels of usage, the effects of these weapons saturate the battle area; maneuver in these situations becomes more difficult. In such cases, tactical plans are dictated by the capability of nuclear weapons to influence the battle.

CONTROL OF NUCLEAR AMMUNITION

Because of the great combat power afforded by nuclear weapons and their limited supply, the commander and staff carefully control the supply, expenditure and resupply of this type of ammunition.

Nuclear ammunition falls into the category of "special ammunition." Special ammunition is ammunition so designated by the Department of US Army because of requirements for extraordinary control, handling or security. Special ammunition includes:

— nuclear and nonnuclear warhead sections, atomic demolition munitions (ADM), nuclear projectiles, and associated spotting rounds, propelling charges and repair parts;

— missile bodies (less missiles combining high density, low maintenance and conventional ammunition features), related components of missile bodies (less repair parts), and missile propellants.

A complete round is included within the meaning of special ammunition. Certain items which are closely relat-

ed to special ammunition are supplied through special ammunition supply channels (e. g., associated test and handling equipment and special tools).

The availability of complete nuclear rounds will not be so great in the foreseeable future as to permit them to be handled by the required supply rate, available supply rate, automatic resupply, and basic load concepts used with conventional ammunition. The system for distributing nuclear ammunition is outlined further on.

An allocation of nuclear rounds is a specified number of complete nuclear rounds authorized for expenditure by a commander during a specified period of time or a specified phase of an operation.

Allocations are expressed as a specific number of complete rounds in terms of delivery system and yield, e. g., two small free rocket (ECHO) 10-KT, or three 8-inch howitzer ... KT.

Each commander who receives an allocation of nuclear rounds considers:

— retaining a portion of his allocation for the attack of targets in support of his own tactical plan;

— allocating a portion of his allocation to his major subordinate unit commanders for support of their tactical plans;

— maintaining a nuclear weapons reserve with which to influence the battle as it progresses, and in anticipation of his needs during future phases of the operation.

In allocating nuclear rounds the allocating commander considers the following factors:

— missions assigned subordinate units. Consideration is given to which units must have weapons for successful accomplishment of their assigned tasks;

— numbers, types and yields of weapons available;

— the number, size, location, and composition of targets that subordinate units may be expected to acquire and engage;

— the ability of organic or supporting delivery units to fire the type weapons allocated;

— the range, reliability, accuracy, mobility, and responsiveness of available delivery means. Troop safety requirements may dictate that smaller yields and more accurate delivery systems be given to subordinate commanders for close-in targets; larger yields are retain-

ed by higher echelons for attack of larger and deeper targets;

— the other combat power available to assist in the accomplishment of the mission such as chemical or biological ammunition, conventional weapon systems, and maneuver units;

— the capability of subordinate units to accomplish the coordination necessary with other headquarters and with the Navy or Air Force;

— the degree of susceptibility to counter-measures of the available weapon systems;

— the restrictions imposed by higher authority on the allocation received;

— requirements for a reserve.

Because of the short range and small radius of effects of the Davy Crockett, this weapon is not normally employed by commanders above brigade level. Commanders at division and higher either allocate such weapons to subordinate commanders or retain the weapons in reserve for later allocation.

ACQUISITION OF SURFACE TARGETS

Target acquisition is that part of intelligence activities which involves detection, identification, and location of ground targets. The information obtained is used for target analysis, target evaluation, and employment of weapons. Information is collected from all sources and agencies.

The effectiveness of a nuclear attack depends to a great extent upon the accuracy, completeness, and timeliness of intelligence. Specific information of target areas, to include location, size, shape, composition, concentration, vulnerability, recuperability, and permanence, is continually sought by all intelligence collection agencies. The degree to which this information is complete and accurate influences the accuracy of the damage estimation and the validity of the target analysis. The degree to which the information is timely influences the effectiveness of the attack.

A detailed plan for the collection of target information is developed and revised continually throughout an operation.

It is essential that commanders and staff officers understand the effects of nuclear weapons, the capabilities and limitations of the various delivery systems, the combat service support requirements involved, and the procedures for employing these weapons. However, these officers receive technical advice from NWEO in the tactical operations center on matters incident to the use of such weapons.

Unitial staff planning guidance normally falls into the following categories: type of targets to be attacked (scheduled or on-call); allocations to subordinate units; and desired nuclear weapon reserve.

The commander's initial staff planning guidance for the use of nuclear weapons varies as to content with the echelon concerned.

At division level, this guidance is normally confined to the type targets to be attacked with nuclear weapons and the weapon reserve desired. The division commander may also have occasion to give guidance as to allocation of weapons to a brigade. In the case of Davy Crockett he may desire to allocate to the cavalry squadron or to a small task force. Because of the immediate and profound impact nuclear weapons have on operations at the division echelon, the commander's guidance normally is quite detailed in the areas mentioned above. He frequently indicates specific weapons that will constitute his nuclear weapon reserve. A division nuclear weapon reserve is retained for attack of targets of opportunity, rather than for future operations.

At corps level, initial staff planning guidance is normally provided concerning the type targets to be attacked with nuclear weapons under corps control, a general guide as to weapons allocation to major subordinate commands, and the general nature of the corps nuclear weapon reserve. Because of the scope and area of corps operations, the corps is the lowest echelon that retains a substantial reserve of nuclear weapons for future phases of an operation. Since corps possesses the resources for delivering a decisive blow on the enemy, command guidance includes the nuclear fires desired in connection with the commitment of the corps reserve maneuver force.

At field army level the commander's initial staff planning guidance is more general than at lower echelons. Since field army plans an operation weeks or even months in advance of the D-day, initial staff planning guidance seldom concerns the attack by field army or specific targets with nuclear weapons. Instead, the field army commander provides guidance that permits the staff to develop tentative allocations of weapons to major subordinate commands for each phase of the army operation, and an appropriate army reserve of nuclear weapons for the entire operation. The army commander also provides guidance in regard to priorities in the employment of nuclear air defense weapons with specific attention to the use of such weapons in a surface-to-surface role. Because of his responsibility in regard to nuclear weapons logistical support, the field army commander provides guidance in this area. This guidance will generally be an expression of desired priorities. Finally, he provides guidance as to his policies (and policies imposed by higher headquarters) concerning limiting requirements. This guidance may include such areas as limitations on fallout, protection of friendly civilians, and avoidance of damage to transportation complexes.

Damage criteria and troop safety considerations are standing operating procedure (SOP)[1] matters. Command guidance in these respects is appropriate only when departures from the SOP are desired. The SOP should state the required coverage to destroy a target, and the required target coverage to neutralize a target. Based on the SOP, the nuclear weapons employment officer determines the extent and nature of damage required, and recommends the weapon system best suited for that task. Similarly, the commander will, as an SOP, desire negligible risk to his own and adjacent forces. The staff, including the nuclear weapons employment officer, automatically take this into account in their analyses and operational planning. If a risk greater than negligible must be taken, or if friendly troops must be warned of the attack, the employment officer so indicates when he makes his recommendations. Creation of obstacles to friendly movement

[1] For details see Part III, Section VII "Target Analysis".

and other undesirable effects are also matters the staff and the nuclear weapons employment officer are normally quite capable of foreseeing and minimizing without being given specific guidance. These limiting requirements may include one or more of the following:

— no significant fallout;

— no damage to particular installation or area;

— significant induced contamination will not be placed on a specific area, or the intensity of the induced contamination near ground zero will be held to a minimum.

DIVISION COMMANDER'S GUIDANCE

The following is an example of a division commander's initial guidance to his staff: "Use no more than three nuclear weapons to neutralize the enemy reserves. Use at least two weapons to support the brigade making the main attack allocate some Davy Crockett weapons to the cavalry squadron and to the commited brigades. Give the remainder of the Davy Crockett allocation to the reserve brigade as a planning allocation. Make sure the reserve brigade is carrying enough weapons to support its planning allocation. Retain the remainder of our weapons other than Davy Crockett in reserve for employment on targets of opportunity."

CORPS COMMANDER'S GUIDANCE

The following is an example of a corps commander's initial guidance to his staff:

"Enemy has organized the area between our current positions and the BLUE RIVER for a determined defense. The decisive battle during the coming operation will be fought west of the BLUE RIVER. Athough we have a limited number of nuclear weapons for this operation, I am willing to expend 30 to 40 per cent of our allocation in penetrating the enemy main and second defense belts and advancing to the BLUE RIVER. Corps fires will be used to engage enemy nuclear delivery means and those reserve maneuver forces which have the capability of adversely affecting the outcome of the battle. These fires will be delivered as soon as the targets are located. These fires, together with the nuclear weapons allocated to the

subordinate units will insure that we inflict maximum casualties and damage to enemy units west of the BLUE RIVER and will insure our successful attack to secure crossing over the BLUE RIVER. Once we are across the BLUE RIVER we must be ready to exploit our crossing and move rapidly through the passes of the SILVER MOUNTAIN and seize the communications center of FOXVILLE. Be extremely cautious in planning the employment of nuclear weapons in the SILVER MOUNTAINS as I want no obstacles to our advance created in these critical areas.

Retain one-fourth to one-half of our nuclear weapons in reserve for the attack to seize FOXVILLE since I anticipate a stubborn enemy defense there, and for the defense against the aggressor counterattacks which are sure to follow when we seize FOXVILLE.

Weapons over 50 KT yield will not be allocated to divisions."

FIELD ARMY COMMANDER'S GUIDANCE

The following is an example of a field army commander's initial guidance to his staff:

"The offensive to seize the passes through the RUFF MOUNTAINS is the most critical part of the coming operation. Once we have seized the passes and repulsed enemy counterattacks we should regroup and advance rapidly to the northeast to seize the INDIA-BRAVO-MIKE industrial complex, linkup with elements of the 12th Army group and destroy the enemy entrapped in the pockets thus formed. With the advance to the RUFF MOUNTAINS so critical I am willing to expend one half of the nuclear allocation to destroy enemy resistance west of the mountains and inflict maximum casualties and damage to his reserves in this area. Plan on a small nuclear weapon expenditure in the exploitation from the mountains to seize the INDIA-BRAVO-MIKE complex. Insure we retain a reserve of nuclear weapons for use during the initial attack to seize the mountain passes, to prevent any sizable reinforcement by reserves now located east of the mountain and to destroy enemy forces entrapped in the pocket.

Surface bursts may be authorized by corps commanders provided that significant fallout is confined to the corps zone of action.

Air defense is SOP. Nuclear weapons allocated to us for air defense purposes will not be employed in a surface-to-surface role without specific approval by me.

The success of this offensive depends heavily upon the delivery of nuclear fires when required. Insure that the special ammunition supply point's (SASP's) supporting the corps are located well forward for this operation and that all nuclear delivery units have a maximum special ammunition load. If required give transportation priority to movement of nuclear weapons."

FIRE SUPPORT COORDINATION

Fire support coordination is the process of planning and employing artillery fire, naval gun fire, and strafing and bombardment by aircraft to assist maneuver elements in the accomplishment of their tactical missions. This planning insures that targets are adequately attacked by appropriate means.

Proper fire support coordination integrates firepower and maneuver. The fire support element of the tactical operations center performs the target analyses that result in a recommended plan for the employment of nuclear weapons. If these plans involve means other than normal surface-to-surface delivery units, they are coordinated as follows:

— atomic demolition munitions with engineer element;

— air-delivered weapons with tactical air support element;

— air defense weapons employed in a surface-to-surface role with air defense element.

During the fire support coordination process, measures are taken to insure that predicted effects of contemplated nuclear fires will not adversely affect projected operations. When undesirable effects of nuclear fires cannot be prevented, the implications of these effects are indicated and alternative courses of action recommended to the commander for decision.

During the process of fire support coordination, a se-

ries of recommendations are developed which will produce the following specific results:

— effective allocation of nuclear weapons;

— proper positioning of weapons to support the allocation;

— establishment of liaison and communications between nuclear delivery units and supported units;

— actions to insure troop safety. The NWEO checks for troop safety as a part of each target analysis. To accomplish this check, it is necessary to have data indicating the location of friendly forces. Procedures, such as phase lines, for the reporting of location and for the control and coordination of movement. During the fire support coordination process, recommendations as to the specific procedures to be employed are developed.

WARNING OF FRIENDLY NUCLEAR STRIKES

Advance warning of a nuclear strike is required to insure that friendly forces do not receive casualty-producing weapons effects. For strikes at distant enemy targets, advance warning is required only for adjacent units and aircraft likely to be affected by such strikes. When a weapon is part of a schedule of fires, there is usually adequate time to alert those personnel in an area where significant effects may be received.

Nuclear strike warning messages are disseminated as rapidly as possible. The requirement for speed will frequently be in conflict with requirement for communication security. Authentication procedures and encoding instructions for nuclear strike warning messages are included in unit signal operation instruction (SOI):

— the amount of information encoded is held to a minimum;

— strike warnings are broadcast in the clear when insufficient time remains for the enemy to react prior to the strike.

Nuclear strike warning messages are given precedence of FLASH.

The content of a nuclear strike warning message depends upon the echelon of command disseminating the message.

Battalion-sized units and above usually have the capa-

bility of plotting the desired ground zero and graphically displaying the areas where significant effects may be received. The message to these units includes:

— a proword indicating that the message is a nuclear strike warning;

— target designation;

— coordinates of desired ground zero (DGZ);

— the minimum safe distance (MSD) in hundreds of meters associated with the accepted risk to warned protected personnel (within this distance it is unsafe to locate troops);

— the MSD in hundreds of meters associated with the accepted risk to warned exposed personnel (within this distance troops must take maximum protection);

— the MSD in hundreds of meters associated with the accepted risk for unwarned exposed personnel (within this distance troops must be in a warned exposed condition);

— if necessary, the distance in hundreds of meters from DGZ to which the troops must shield their eyes from dazzle. Troops must be cautioned to shield their eyes when they are expected to take any action within 15 minutes of a night nuclear attack;

— expected time of burst. The SOP should specify the allowable time limits within which the weapon must be delivered, failure to deliver the weapon within this allowable time limit requires postponement of the fire mission and initiation of a new warning. During the period of time the weapon may be delivered, personnel observe the protective measures required;

— a requirement to acknowledge. The SOP should indicate the meaning of the acknowledgement; e. g., all platoon-sized units in the affected area have been warned.

A unit that is disseminating a message to company (battery) level transmits a message to each unit within those distances from DGZ shown in Fig. 28. This message contains specific orders for the protective measures to be implemented by that unit. The message should include:

— a proword indicating that the message is a nuclear strike warning;

— a brief prearranged message which directs the unit to observe a specific protective measure. The SOP should state the period of time during which personnel must remain protected;

— expected time of burst.

All available communication means are used to permit rapid dissemination of warnings of the employment of nuclear weapons against targets of opportunity. These means include:

— sole purpose telephone circuits, wire or radio relay;

— voice radio nets;

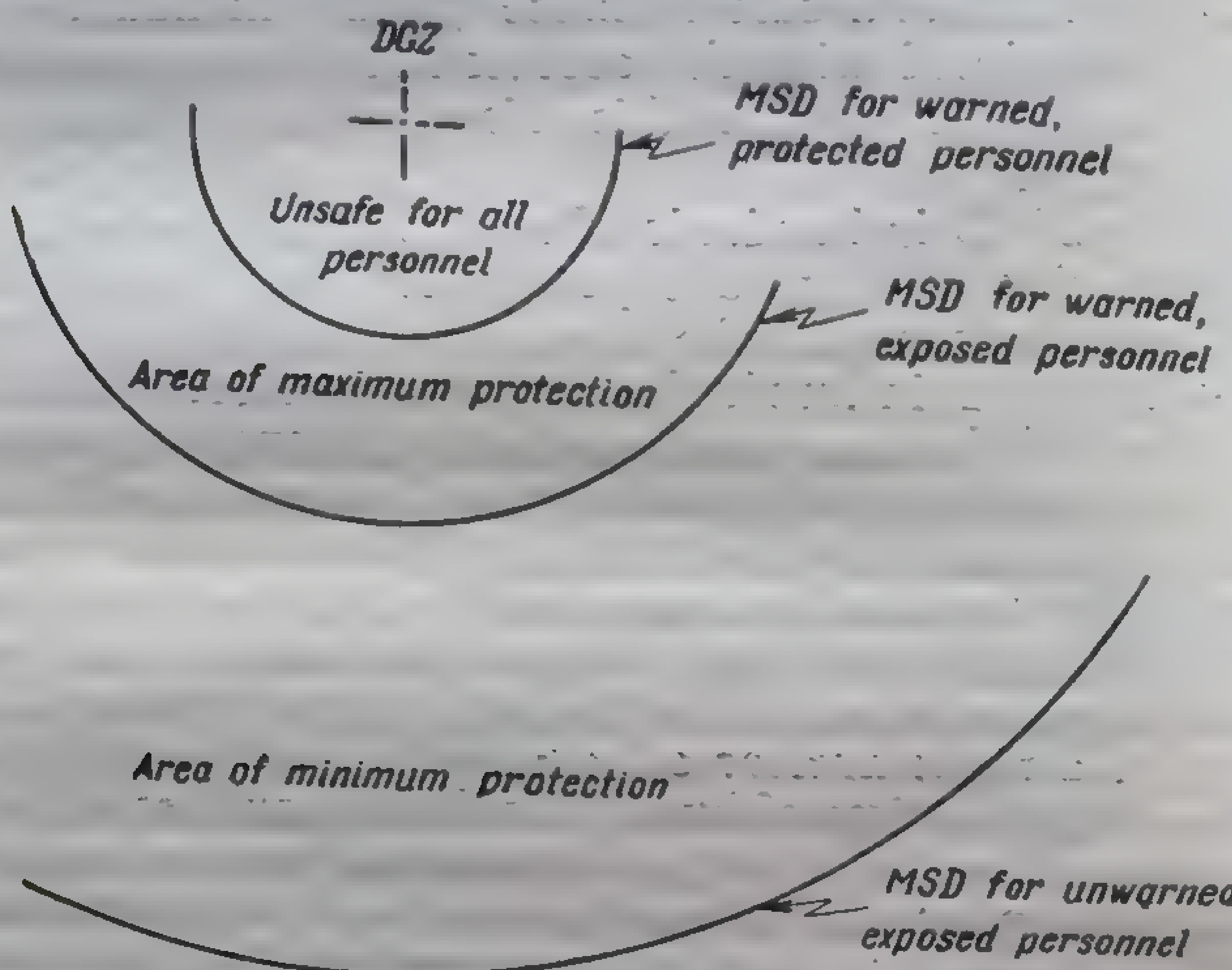

Fig. 28. Zone of warning for nuclear strikes.

— continuous wave (CW) and radio-teletypewriter (RTT) nets;

— one-way voice radio nets. This communication does not give the recipient the capability of acknowledgement; the recipient may be required to acknowledge over a different means of communication. The range and coverage of this net may cause the message to be sent to units that do not need to be warned.

A fragmentary warning order may be issued to alert unit personnel in an area where they may receive the effects of a weapon being considered for employment. In this manner the personnel are cautioned to remain alert for a followup message which will cancel, confirm or alter the warning.

Effective liaison requires that notification of planned strikes be passed to adjacent units.

FIRE REQUESTS

A commander having a requirement for nuclear fires for which he has no allocation requests an allocation or the delivery of nuclear fires from the next higher command. Simultaneously the fire direction center or air support operations center is alerted. Requests contain sufficient information to permit a complete evaluation of the fire mission. As a minimum, a request contains a description of the target, the results desired and the desired time of burst. The request may contain additional information such as limiting requirements, location of desired ground zero, acceptable risk to friendly troops, or location and degree of protection of nearest friendly troops. If the target has been analyzed by the requesting agency, the request for fires may specify the desired weapon and yield.

The commander who has an allocation approves or disapproves the request. In some cases he may submit a request to the next higher commander for a weapon more suitable than the weapons in his own allocation.

Upon approval or disapproval of a fire request, the requesting agency is notified. Whenever possible, a commander who disapproves a request provides the requesting agency with the reason for the disapproval.

FIRE ORDERS

Once a fire mission has been approved, fire support agencies are given the necessary orders to cause the weapons to be delivered on the target.

Orders to Army delivery units include:

— unit to deliver the weapon;

— firing site, if applicable;

— delivery system/yield;

— height of burst in meters, or in the case of radar-fuzed weapons, height of burst option or radar step number;

— when applicable, fuzing option desired, e. g., contact backup or contact preclusion;

— desired ground zero;

— time of burst;
— resupply instructions, if applicable.

If air-delivered weapons have been allocated to an Army unit, the message to the air support operations centre (ASOC) includes:

— yield;
— maximum permissible CEP;
— height of burst in meters, or in the case of radar-fuzed weapons, height of burst option or radar step number;
— when applicable, fuzing option desired, e. g., contact backup or contact preclusion;
— desired ground zero;
— time of burst;
— applicable coordination measures. For example: (1) special signal procedures such as the marking of the target, marking of the initial point, and abort signals, (2) flak suppression measures, (3) special air defense coordination procedures.

Early notification to the delivery unit reduces delays in firing. Advance information with which to occupy firing sites, compute firing data, and prepare the nuclear round is desirable. On some occasions, this information is given to the delivery unit prior to the time a decision is made to employ the weapon.

Fire support agencies may be ordered to prepare an alternate nuclear weapon system (either of the same type or of a different type) or to plan nonnuclear fires in the event of failure of the first weapon. This should be done when a less reliable weapon system is employed.

EMPLOYMENT OF ATOMIC DEMOLITION MUNITIONS

Certain nuclear weapons are designed so that they may be emplaced at the desired ground zero by engineer personnel or by other qualified personnel who have been specially trained. Nuclear weapons employed in this manner are called "atomic demolition munitions (ADM)." Generally, ADM are employed against the same type targets as nonnuclear demolitions. ADM are also used to create large scale obstacles and to produce fallout but have the additional advantage of delaying repair or use of an area because of residual radiation. Once a decision has been

made that ADM may be employed, allocations are made to the commander within whose area the total effects of the burst will be contained.

During retrograde movements, ADM's are emplaced in terrain held by friendly elements. ADM employed in this manner are integrated with barrier plans and denial plans. Provisions are made for demolition guards and communications. Procedures to detonate the ADM are specifically directed by the commander who directs the installation of the ADM; these procedures identify the commander or other person who is authorized to order detonation.

ADM may be employed to produce fallout, to destroy structures and to produce cratering, fires and tree blowdown. They may also be used against installations that are not likely to be moved prior to the time the weapon detonates. They have specific applications in destroying very hard targets such as tunnels, dams, airfields, railroad yards, ports, causeways, major bridges, and underground installations; in denying key terrain or facilities to the enemy; and in creating obstacles to enemy movement.

USE OF FALLOUT

Intentional surface bursts are employed whenever fallout is desired. Fallout is used as the principal desired effect whenever it contributes to the accomplishment of the mission in a better manner than the initial effects.

The lethal area of a weapon is greatly extended by the production of fallout. Any increase in yield produces an increase in initial effects; a correspondingly greater increase in the fallout pattern occurs with the same increase in fission yield.

Because of the large area covered by fallout patterns authority for the use of surface bursts is held at a higher level than is normal for airbursts.

Fallout is employed to restrict the use of areas to the enemy, as an obstacle to his movement, or as a spoiling attack to throw his tactical plans off balance. When target information is vague, or when the target area appears to be thinly occupied, the large area covered by a fallout pattern gives special advantage. As discussed below, present methods of predicting fallout do not give the capability of accurate target coverage estimation.

Exploitation of a friendly burst is accomplished through coordination of firepower and maneuver elements while it is preferable to have friendly units avoid the fallout pattern, the pattern can be crossed with reduced risk if the troops cross quickly and if they have a good degree of radiation protection while crossing.

As is the case with other obstacles, a fallout pattern can be crossed by a determined enemy. Pattern crossings can be made with relative impunity by highly mobile, well shielded troops, such as the personnel in tank units. The crossing of the pattern can be made more costly to the enemy regardless of the crossing means used — if it is covered by fire. Repeated surface bursts in the same area may be required to maintain the restricted area at the desired level of contamination.

The effect of fallout on future operations is considered when planning surface bursts. Fallout assumes great importance if a given locality is to be used a short time after the burst, especially if prolonged occupancy is foreseen.

A fallout prediction is prepared when friendly surface bursts are employed.

Standing operating procedures in all units provide for radiological monitoring whenever surface bursts are employed. These standing operating procedures also establish methods of assembling the information necessary to make radiological contamination charts.

After radiological contamination charts have been plotted, total dose-stay time calculations are performed. Based on the total dose expected to be received during movement through the fallout pattern, the commander estimates the risk involved in executing his planned maneuver. As a result of this evaluation, the commander may change his maneuver plan, accept a risk of increased casualties, or delay his movement until the pattern has decayed to an acceptable level.

ESTIMATE OF THE SITUATION

An estimate of the situation is a logical and orderly examination of all factors affecting the accomplishment of the mission.

The commander may decide that a suspected target is so important that he must attack it whether or not

friendly intelligence agencies have been able to collect significant information on the target.

Conversely, the commander may decide that a target is not of sufficient importance to warrant attack unless there is considerable proof that attack of the target would be remunerative.

Once targets have been evaluated and given a priority for attack, the commander determines whether to engage them with nuclear fires, nonnuclear fires, maneuver or some combination of these means.

There are many considerations which influence the decision to attack a target with nuclear weapons.

Time is required for target evaluation, target analysis, fire direction and preparation of the round for firing.

Time is required to:

— warn subordinate units;

— coordinate with adjacent units into whose sector weapons effects may extend;

— notify friendly aircraft.

The ability of the enemy to interfere with our nuclear attack influences the decision. Means by which the enemy might interfere with our attack are attack of our nuclear delivery means with either a maneuver force or firepower, electronic countermeasures, or interference with command and control facilities.

The results of target analysis affect the estimate of the situation. The commander may consider that the results expected from a nuclear attack are insufficient to warrant the expenditure of a nuclear weapon. If the reliability of the weapon system is low, the commander may consider that the importance of the target is so great that a more reliable means be used in its attack.

Targets of a magnitude appropriate for attack with nuclear weapons are frequently ill-defined. Consequently predictions of target coverage should not be given undue weight by the commander in making his decision.

As a result of the estimate of the situation, the commander decides the proper method of engaging each target. The authority to engage a target with a nuclear weapon is normally retained personally by the commander. In appropriate circumstances, the commander delegates this authority to a specifically designated representative.

TACTICAL DAMAGE EVALUATION

Tactical plans are based on the condition of the target area predicted in the target analysis. Once the nuclear attack has been made, the primary or an alternate plan is executed depending on the results achieved. In some cases, the decision may be made to fire a backup weapon. The impact of damage, casualties, obstacles, or contaminated areas on the planned operation are considered prior to the commitment of exploiting forces. Situations may arise in which changes of direction or even cancellation of an attack is possible or necessary.

Following a friendly nuclear burst, every reasonable effort is made to determine the damage to enemy forces and their reaction to the attack and to obtain information concerning residual radioactivity, fires and obstacles.

DISTRIBUTION OF NUCLEAR AMMUNITION

Commanders and staff officers continuously evaluate the capabilities and limitations of logistical systems to support nuclear weapons employment. Because of the decisive character and limited availability of nuclear ammunition, the distribution of this ammunition is an operational as well as a logistical problem.

The specific quantity of special ammunition to be carried by a delivery unit is termed special ammunition load (SAL). The specific quantity of various special ammunition items to be stocked in an ordnance unit or installation is termed special ammunition stockage (SAS).

Replenishment of SAL's and SAS's is accomplished by directed individual issue, automatic issue, or a combination of these.

Nuclear rounds are stored and issued to delivery units by ordnance special ammunition units. The complete nuclear round is issued to nuclear weapon delivery units at special ammunition supply points (SASP) using supply point distribution procedures.

TACTICAL ACCOUNTABILITY

The decisive character of nuclear weapons and their limited availability make detailed record keeping necessary. Planning information required for employment of

nuclear ammunition is given in Fig. 29. This example demonstrates use of the sample charts by a corps headquarters.

ALLOCATION AND DISTRIBUTION SUMMARY																					HQ, ··· Corps Posted 121800 Jul
Allocation (Delivery System/Yield)																					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
																AIR DELIVERED					
	TOTAL	MRC/Bravo/1KT	LRC/Charlie/2KT	LRC/Delta/5KT	LFR/Delta/5KT	LFR/Echo/10KT	LFR/Foxtrot/20KT	LGM/Charlie/2KT	LGM/Delta/5KT	MGM/Foxtrot/20KT	MGM/Hotel/100KT	HGM/Juliet/500KT	ADM/Alfa/.5KT			Air/Echo/10KT	Air/Foxtrot/20KT	Air/Golf/50KT			Remarks
··· Corps 8-18 July	50	6	3	3	4	6	5	4	5	4	2		3			1	2	2			
Expended to date	15		1	2	1	2	2	3	1	3											
Unexpended	35	6	2	1	3	4	3	1	4	1	2		3			1	2	2			
Allocation of unexpended rounds: Corps targets	4									1	1						1	1			
Allocation of unexpended rounds: ··· Inf Div	6	1			1		1	1	2												For period 11-13 Jul
Allocation of unexpended rounds: ··· Mech Div	5	1	1			2	1														
Allocation of unexpended rounds: ··· Armd Div	3	1			1				1												
Allocation of unexpended rounds: Corps res	17	3	1	1	1	2	1		1		1		3			1	1	1			
··· Army Res as of 12 Jul	150	21	12	9	9	14	11	8	13	4	7	6	8			7	8	13			For period through 1 Aug

Distribution of 1st Corps special ammunition load as of 121800 Jul

··· Corps in delivery units	17	1	3	1	2	2	2	3	3	1											
Corps in SASP's	17	5	2	1		1		1	1	1	2		3								
··· Inf Div	6	2			2		2														
··· Mech Div	5	1			1	2	1														
·· Armd Div	4	1			1	2															
TOTAL	49	10	5	2	6	7	5	4	4	1	2		3								

LEGEND

MRC-Medium-range cannon. MGM-Medium guided missile

LRC-Long-range cannon. HGM-Heavy guided missile.

LFR-Large free rocket. ADM-Atomic demolition munition

LGM-Light guided missile.

Fig. 29. Allocation and distribution summary.

Fig. 29 portrays information on allocations, expenditures and rounds carried in delivery units and SASP's. All entries indicate complete round information, i. e. warhead section or shell and the associated missile and/or propellant required to deliver the weapon on a target.

nuclear ammunition is given in Fig. 29. This example demonstrates use of the sample charts by a corps headquarters.

ALLOCATION AND DISTRIBUTION SUMMARY — HQ, ··· Corps, Posted 121800 Jul

Allocation (Delivery System/Yield)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
																AIR DELIVERED					
	TOTAL	MRC/Bravo/1KT	LRC/Charlie/2KT	LRC/Delta/5KT	LFR/Delta/5KT	LFR/Echo/10KT	LFR/Foxtrot/20KT	LGM/Charlie/2KT	LGM/Delta/5KT	MGM/Foxtrot/20KT	MGM/Hotel/100KT	HGM/Juliet/500KT	ADM/Alfa/.5KT			Air/Echo/10KT	Air/Foxtrot/20KT	Air/Golf/50KT			Remarks
···Corps 8-18 July	50	6	3	3	4	6	5	4	5	4	2		3			1	2	2			
Expended to date	15		1	2	1	2	2	3	1	3											
Unexpended	35	6	2	1	3	4	3	1	4	1	2		3			1	2	2			
Allocation of unexpended rounds: Corps targets	4									1	1						1	1			
Allocation of unexpended rounds: ··Inf Div	6	1			1		1	1	2												For period 11-13 Jul
Allocation of unexpended rounds: ···Mech Div	5	1	1			2	1														
Allocation of unexpended rounds: ···Armd Div	3	1			1				1												
Allocation of unexpended rounds: Corps res	17	3	1	1	1	2	1		1		1		3			1	1	1			
··· Army Res as of 12 Jul	150	21	12	9	9	14	11	8	13	4	7	6	8			7	8	13			For period through 1 Aug

Distribution of 1st Corps special ammunition load as of 121800 Jul

··· Corps in delivery units	17	1	3	1	2	2	2	3	3	1											
··· Corps in SASP's	17	5	2	1		1		1	1	1	2		3								
··· Inf Div	6	2			2		2														
··· Mech Div	5	1			1	2	1														
·· Armd Div	4	1			1	2															
TOTAL	49	10	5	2	6	7	5	4	4	1	2		3								

LEGEND

MRC-Medium-range cannon. MGM-Medium guided missile

LRC-Long-range cannon. HGM-Heavy guided missile.

LFR-Large free rocket. ADM-Atomic demolition munition

LGM-Light guided missile.

Fig. 29. Allocation and distribution summary.

Fig. 29 ... information on allocations, expenditu-

Fig. 29 shows also the location of delivery units retained under the direct control of the headquarters and indicates the number of complete nuclear rounds present in each of these delivery units. Firing points, rendezvous or concealment areas, unit service areas, SASP locations and firing capabilities of each delivery unit are shown on this overlay.

Information for use by the operational staff in addition to the figure described above is shown in special charts. When a large number of weapons is in the SAL, a separate ammunition status chart for each type delivery system available to the commander (e. g., Little John, Honest John, and Sergeant) should be placed on the operations board together with the air-delivered weapon status chart. The operations board is used in conjunction with the partial nuclear ammunition summary and fire capabilities overlay to visualize the actual distribution of nuclear rounds.

Section VI

OPERATIONS IN RESIDUAL RADIATION AREAS

Nuclear radiation that results from a nuclear explosion and persists longer than one minute after burst is termed residual radiation.[1] This residual radiation can contaminate the airspace over the area of operations, or the terrain itself, or both, depending primarily on the height of burst of the weapon. Contamination of the airspace is for a relatively short period of time, and the hazard to aircraft flying within the area is minor. Residual radiation consists primarily of gamma and beta radiations, both of which present a serious personnel hazard. The gamma radiations are by far the more important because of their range and penetrating power. Residual radiation can appear on the ground as induced contamination found within a relatively small circular pattern around ground zero; and as fallout, which is found in a large, irregular pattern encompassing ground zero and extending for long distances downwind from the burst point.

[1] See also Part II, Section III.

PREDICTION OF FALLOUT AREAS

A tactical fallout prediction system must be a compromise between speed and simplicity on the one hand, and the time-consuming complexity that increases accuracy on the other. The present U. S. Army method of predicting fallout gives only a warning sector, somewhere within which most of the fallout is expected to occur.

The prediction results in portrayal of an area which is expected to contain most of the significant fallout. A fairly detailed prediction is prepared by the field staff based on the best available weather and weapon data. Battalion and lower units use a template to estimate the hazard area; this template is applied using less precise data. Both predictions present a graphic portrayal of the expected hazard. The hazard area is subdivided into:

— an area within which countermeasures may have to be taken immediately, and

— an area where early, but not immediate action may have to be taken to counter the threat of unacceptable doses.

The basic inaccuracies in fallout prediction permit this method to be used in depicting suspect areas for early monitoring and survey, and for planning movement of units, but not as a basis for executing operational moves. The method also permits prediction of the areas outside which friendly troops will have relative immunity from the fallout hazard.

MONITORING AND SURVEY

Radiological monitoring is the use by a person (monitor) of radiac instruments to detect and measure ionizing radiation. Radiac instruments are of two types: survey meters to measure dose rate, and dosimeters to measure total dose. Monitoring provides warning of a hazard which, except for the use of radiac instruments, would go unmeasured. Monitoring is included in normal reconnaissance and intelligence activities and does not interfere with the primary mission of the monitor or his unit.

Radiological survey is the systematic, organized use of survey parties whose mission is to determine the location, extent, and dose rate of residual radiation in an area.

When monitoring data are insufficient to the needs of brigade, division and higher echelons, surveys may be directed to obtain essential information upon which to base tactical and combat service support plans. The chemical officer supervises the planning of surveys, the processing of survey data, and the marking of hazardous areas. Commanders at all echelons are responsible for the training of survey parties, and for performing surveys as required or directed.

The information gained from the activities of radiological monitors and survey parties provides a basis for decisions regarding the requirement for protection, entry, stay, and departure times from contaminated areas, and movement of units and supplies.

CONTROL AND COMMUNICATIONS

The problems of command control multiply as tactical units disperse to avoid detection and attack. Even in the best trained units, some confusion will follow a nuclear attack because of surprise, shock, physiological and psychological casualties, materiel damage, and reduced visibility. An important means of maintaining or restoring command control is the communication network, both within and between units.

Unless strictly controlled, communication facilities will be saturated in the immediate post-attack phase by units desiring to receive or impart information. The SOP specifies what reports are to be rendered or exchanged. All other transmissions are suppressed. Communication equipment is protected from physical damage from weapon effects in order to preserve this vital control element. The SOP specifies the emergency use of all communication means, restrictions, and alternate means. It also specifies the conduct of units in the event all communications are lost.

BASIC RADIOLOGICAL SURVEY METHODS

There are four basic radiological survey methods; rapid survey, detailed survey, supplementary monitoring, and personnel monitoring. All four require the use of radiac instruments.

The most rapid means of estimating the extent of radiological hazards is by an aerial survey, using helicopters. The great advantage of such a survey is that it can be carried out regardless of the destruction or the intensity of the radiation in the bombed area. Because of their long range in air, gamma rays coming from radioactive contamination on the surface can be detected by sensitive instruments at the height of several thousand feet. Slow flying aircraft and helicopters carrying ordinary survey meters could fly over an affected area in a set pattern and record the gamma radiation intensities encountered. From the radiation intensities measured at a known altitude, it is possible to obtain a rough estimate of the dose rate, in roentgens per hour, which would be encountered on the surface of the ground or water. Experimental and theoretical studies have indicated that the dose rate on the surface will be somewhere between 100 to 1,000 times as high as the reading got at 1,000 feet. Therefore, ground surveys must be made to obtain more exact dose rate readings.

The aerial survey is important because it can provide valuable information which might be impossible to get in any other way. Nevertheless, it can serve only as a rough guide. It is not a substitute for a ground survey, at least in the case of those areas which are of any military importance. Early ground monitoring, either supplementary to or independent of the aerial survey, could be carried out by means of a tank or armored car with a detecting unit mounted on the outside of the vehicle.

After the first survey parties have measured and reported readings which allow the general extent of the contaminated areas to be plotted, subsequent survey parties can proceed with more detailed monitoring of the area as a whole.

The purpose of a detailed survey is to: (1) find the radiation level of specific objects or locations within the contaminated area of military interest, (2) locate regions of higher than average intensity ("hot spots"), and (3) establish with greater accuracy the position of the outer line of contamination and the danger line. Detailed survey parties will carry signs and marking equipment with which they can mark the outline of the contaminated area,

roads which are clear of obstructions, and the location of any "hot spots."

Detailed radiological procedures are used in monitoring contaminated areas and objects. These procedures will be based on the following:

1. Radiac instruments or their probes must always be held at the same distance from the objects being monitored. Otherwise, the reading will not represent a true picture of the radiation intensity.

2. The level of contamination will vary with locations, soil conditions, type of surface, and positions of objects within the area.

3. Objects having poor drainage will frequently give higher intensity readings than those having good drainage.

4. Single intensity reading for an area are of little importance; a relatively large number of readings are needed to give an accurate picture of the radiation intensity.

5. Monitoring personnel will record the intensity, time, and place of each reading.

6. Survey parties will use existing roads except perhaps in a few front-line situations.

7. Survey parties will use vehicles, if possible, since this will permit the most rapid approach and withdrawal. Use of roads also help plotting personnel to locate the positions at which readings are taken.

8. If the center of the impact area is known, survey parties will proceed toward it taking periodic readings until a designated point or a specified radiation intensity reading is reached. They will then return, preferably by another route in order to obtain a second set of readings through a different area.

9. Members of survey, will wear special clothing which they can discard. Neverheless, each individual should be thoroughly monitored to make sure that no radioactive material has become attached to his body.

The supplementary survey involves detailed monitoring of such things as water and food supplies; bodies of water, such as bays, lakes, harbors and sizable reservoirs; and of specific buildings and installations which it might be desirable to occupy later. Water areas will be monitored, first by a preliminary survey made from slow-flying

aircraft, then by more detailed survey operations using small, fast-moving surface craft.

One of the most urgent matters will be the monitoring of food and water supplies to prevent the eating or drinking of radioactive material.

All forms of armament or equipment in the contaminated area which are handled or worn by personnel should be subjected to detailed examination before use.

All personnel caught in a contaminating attack should be monitored at a control point as a part of the casualty evacuation process.

ISOLATING CONTAMINATED AREAS

A standard system for marking areas contaminated by atomic agents has been adopted by nations included in the

Fig. 30. Marking signs of contaminated areas (radioactive agents):
a — the front side facing the non-contaminated area; *b* — the reverse side facing the contaminated area.

North Atlantic Treaty Organization. These standard survey markers are illustrated in Fig. 30. Each marker is in the shape of a right-angled isosceles triangle with a base of approximately $11\frac{1}{2}$ inches and sides of approximately 8 inches. The markers may be made of cardboard, metal, wood, plastic, or other rigid material. Three holes are punched in each marker to facilitate rapid placement.

The surface of each marker, facing away from the contaminated area, that is, toward a person approaching the contamination. The atomic warfare (AW) marker has a white background with broad black stripes dividing it into

three small triangles each of which has the word "atom" lettered in black along one side.

The surface facing the contamination is white with black lettering. The word "atom" appears in the three positions previously described for the front surface of the marker. Also included on this inward side in the center of the marker and in black letters is the date of the placement of the marker as well as any other details deemed pertinent, such as the time and the radiation intensities at that point.

RADIOLOGICAL CENTER

The radiological center (RADC) at division, corps, or army headquarters is the control group which plans and supervises radiological surveys as required. Control parties below division level may be designated to perform the same control functions as a RADC.

The radiological center is staffed by one officer and four enlisted personnel, who are under the staff supervision of the chemical and radiological officer of a division, corps, or field army headquarters. Cellular type RADC teams may be provided as needed to augment the organic teams. The principal functions of a RADC are to:

— direct, supervise, and coordinate radiological surveys;

— receive, process, and evaluate monitoring and survey data;

— collate and disseminate radiological information in usable form;

— predict fallout from weapons employed by the enemy and, when directed, predict fallout from friendly weapons.

Radiological centers at division and corps usually operate within or near the Fire Support Coordination Center and at field army, in the G2-G3 operations section of the army operations center. Cellular teams may be established in field army rear areas to assist the rear area security control center (RASCC) located at the field army main command post or the alternate RASCC at the field army rear command post.

TERRAIN

Gross terrain features such as hills, ridges, forests, and stream beds offer appreciable protection from weapon effects. Terrain interposed between a nuclear detonation and a unit can protect that unit from all thermal effects and significantly reduce the blast and initial nuclear radiation effects. The regularity, condition, and nature of the reflecting surface affect the distance to which blast overpressures will extend on the ground. Forests beyond the range of significant tree blowdown offer protection, in the form of thermal shielding to troops deployed therein. Protective terrain features should be a consideration in the selection of movement routes and bivouac areas.

Section VII

TARGET ANALYSIS

FACTORS CONSIDERED IN TARGET ANALYSIS

Target analysis is an examination of the characteristics of a target to determine its vulnerability to weapons attack. The purpose of analyzing a target is to select the best available weapon for attack of the target and to predict the condition of the target area after attack. This section discusses in general terms the procedures for target analysis.

Target analysis is based on the following assumptions:

— reliability. Casualty and damage estimation is predicated on the assumption that a nuclear weapon will get to the target area at the desired time and a nuclear detonation will take place. Since many delivery systems do not provide a high assurance of successful delivery, it is necessary to provide an alternate means to attack the target in case the first weapon fails to function properly. This alternate means may be another nuclear weapon, nonnuclear firepower, or maneuver forces, depending on the nature and importance of the target and the alternate means available;

— targets. When intelligence indicates the size and shape of the target, and the distribution of elements

within the target, these data are used by the target analyst. Otherwise, the target elements are assumed to be uniformly distributed, and the area is assumed to be circular. The radius of the target is based on the best information available;

— atmospheric conditions. The effect of atmospheric conditions on blast and radiation is not usually considered by the target analyst. In cases of heavy rain or snow in the target area, weapon effects radii will vary slightly from those assumed;

— terrain. Except for steep, high mountains, effects of terrain are generally neglected when making target analysis. If a weapon is burst in a valley, shielding of effects may occur outside the valley with reinforced effects within the valley.

SYSTEM ERRORS

Dispersion influences the selection of desired ground zero (DGZ), and desired height of burst. It also affects such factors as damage to the target, troop safety, fallout, tree blowdown, and induced contamination. Consideration is therefore given to delivery errors.

Effect of Horizontal Dispersion. There is a dispersion pattern unique to each type of nuclear weapons delivery system. Cannon and rocket artillery form a generally elliptical pattern whereas guided missile rounds and air delivered weapons form a circular pattern. Since nuclear target analysis is premised on a "single shot", it is assumed that the distribution of errors connected with nuclear delivery systems will follow the laws of probability. It is also assumed that gunnery techniques will place the center of the "dispersion pattern" at the desired ground zero.

It is apparent that a burst occurring at the outer limits of the dispersion pattern will cause the center of the weapon effects to be offset from the desired ground zero. Because the desired ground zero is usually selected at the center of the target, a burst near the outer limits of the dispersion pattern may result in a substantial decrease in the damage to the target.

Fig. 31 shows a burst occurring at the center of the target. In this case, about 30 per cent of the target is covered by the radius of damage.

Fig. 32 shows a burst occurring at the outer edge of the elliptical dispersion pattern. In this case, none of the target is covered. Obviously, the size and shape of the target, the radius of damage and the size and shape of the dispersion pattern affect the amount of the target that will be damaged by a single burst.

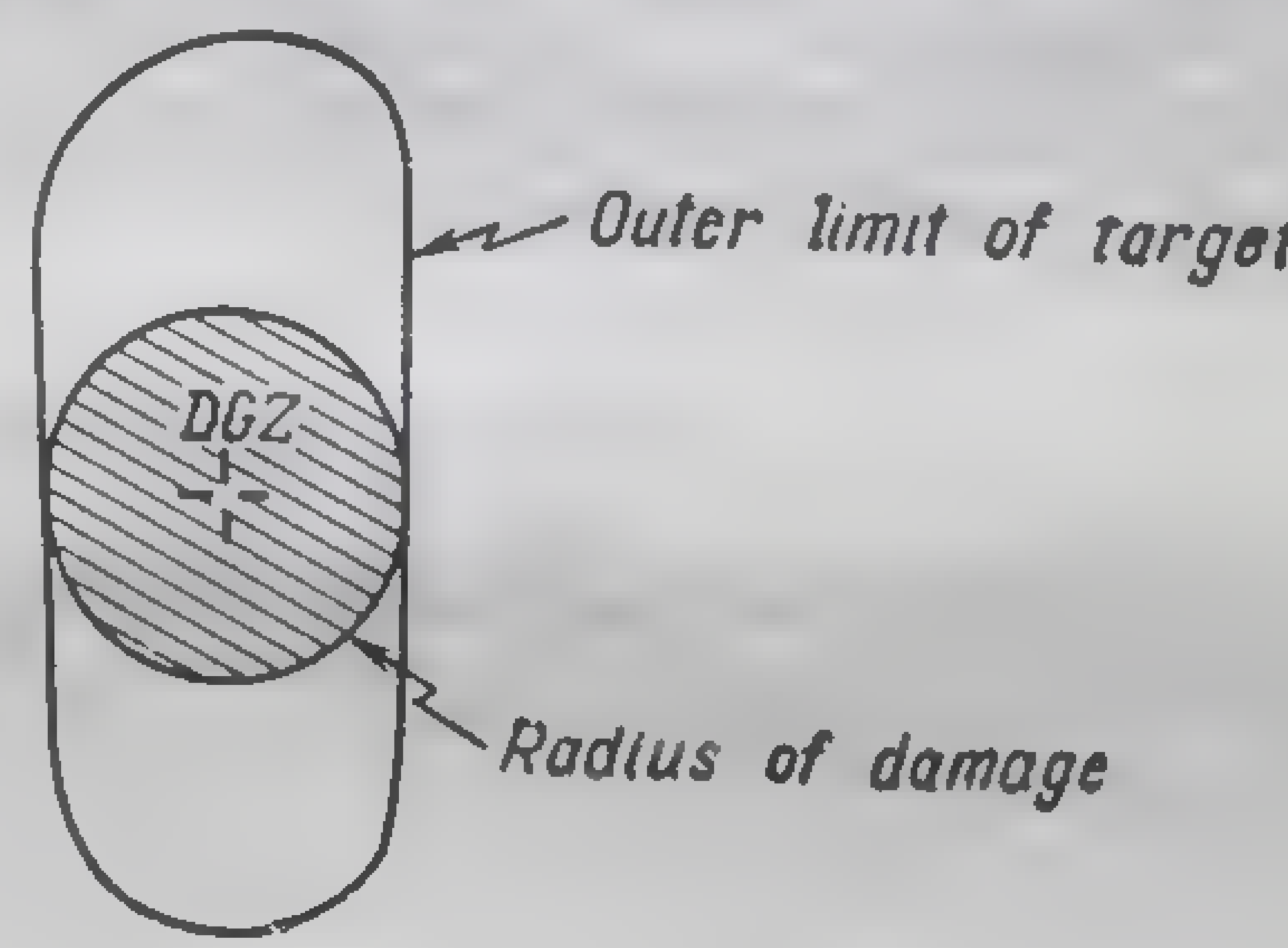

Fig. 31. Burst occurring at target center.

In order to consider this, the target analyst assumes that the burst will occur near the outer edge of the dispersion pattern, and estimates the fraction (per cent) of the target covered by the weapon effect of interest. Under these circumstances, there is a high assurance that the weapon will cause at least that fraction of damage.

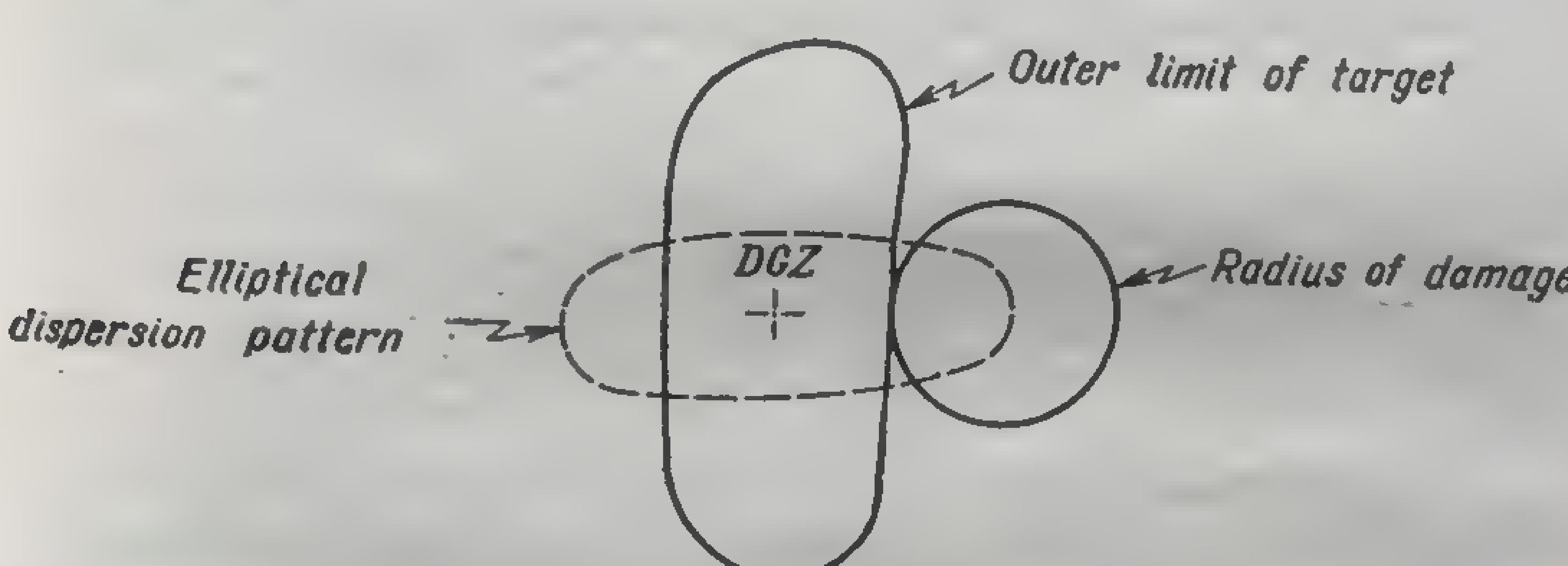

Fig. 32. Burst occurring at outer limit of dispersion pattern.

Effect of Vertical Dispersion. The burst pattern in the air formed by a large number of weapons set with a timer fuze to detonate at the same height of burst, and delivered under nearly identical conditions, is ellipsoidal (shaped like an egg). The height of burst distribution pattern extends above and below the desired height of

burst. It is apparent that a large vertical error may result in a burst occurring a significant distance above or below the desired height. In such cases, the weapon may detonate close enough to the surface to produce fallout or so high in the air that the effects on the target will be significantly reduced. Consequently, vertical dispersion is considered in selecting a height of burst. Radar fuzes greatly reduce the problem of vertical dispersion.

DATA FOR TARGET ANALYSIS

Special tables have been compiled to present the data to be used in target analysis. The basic tables are referred to as weapon selection tables (WST). The weapon selection tables consist of coverage tables, troop safety tables, casualty and damage tables, and contingent effect tables.

The coverage tables present the information with which to estimate damage. A set of indexes is presented which simultaneously consider delivery errors, weapon effects, and target size and composition. For a given yield and delivery system at a given range and height of burst option (impact burst, low airburst or high airburst) employed against a specified target. the index gives an estimate of the damage that can be expected from the attack. Each coverage table also presents the radius of damage for each range and height of burst option. The indexes and radii of damage have been computed using the casualty or damage-producing effect — blast or nuclear radiation — that extends the greatest distance. This effect is referred to as the governing effect.

The troop safety tables simultaneously consider delivery errors, weapons effects and the risk of producing casualties among friendly troops in a particular condition of vulnerability. The tables give the minimum distances that friendly troops must be separated from the desired ground zero for various conditions of risk and vulnerability. These distances are known as the minimum safe distances (MSD).

In *the basic troop safety tables*, these minimum safe distances are shown for each

— delivery system;

— yield;
— height of burst option;
— degree of risk to friendly elements;
— condition of protection (or vulnerability) of friendly troops;
— range.

Because of the influence of delivery errors, the orientation of troop dispositions with respect to the desired ground zero and direction of fire will affect the minimum safe distance. The basic troop safety tables are designed for a direction of fire perpendicular to the friendly dispositions. Supplementary tables are provided for other directions of fire and for those dispositions which are not generally linear.

The casualty and damage tables consider only weapon effects and height of burst. For each weapon, radii of damage for use against various target elements are shown.

The contingent effect tables consider only weapon effects. For each weapon, the tables present the distance to which various effects will extend. These effects are:

— induced radiation;
— tree blowdown;
— safety radii for aircraft in flight;
— fire areas;
— crater dimensions.

DESIRED RECOMMENDATIONS

A target analysis is conducted in order to select the best weapon for attack of a target. After the target analysis has been completed recommendations are presented to the commander. The recommendations should include:

— weapon system;
— height of burst option;
— desired ground zero;
— time of burst;
— estimated results;
— troop safety.

Weapon System. The weapon system is shown by both delivery system and yield. Example: Small free rocket (CHARLIE) 2 KT or Honest John... KT.

Height of Burst (HOB) Option. The height of burst option will normally be indicated as low air, high air, or impact. Exact height of burst in meters is required by delivery units when a timer-fuzed weapon is employed, and is included in the fire order. Generally, the recommendation to the commander need include only the height of burst option, which indicates the significance of surface contamination.

Desired Ground Zero. The desired ground zero (DGZ) is the point on the earth's surface at which, above which, or below which, the detonation is desired (Fig. 33). It is generally designated by map coordinates.

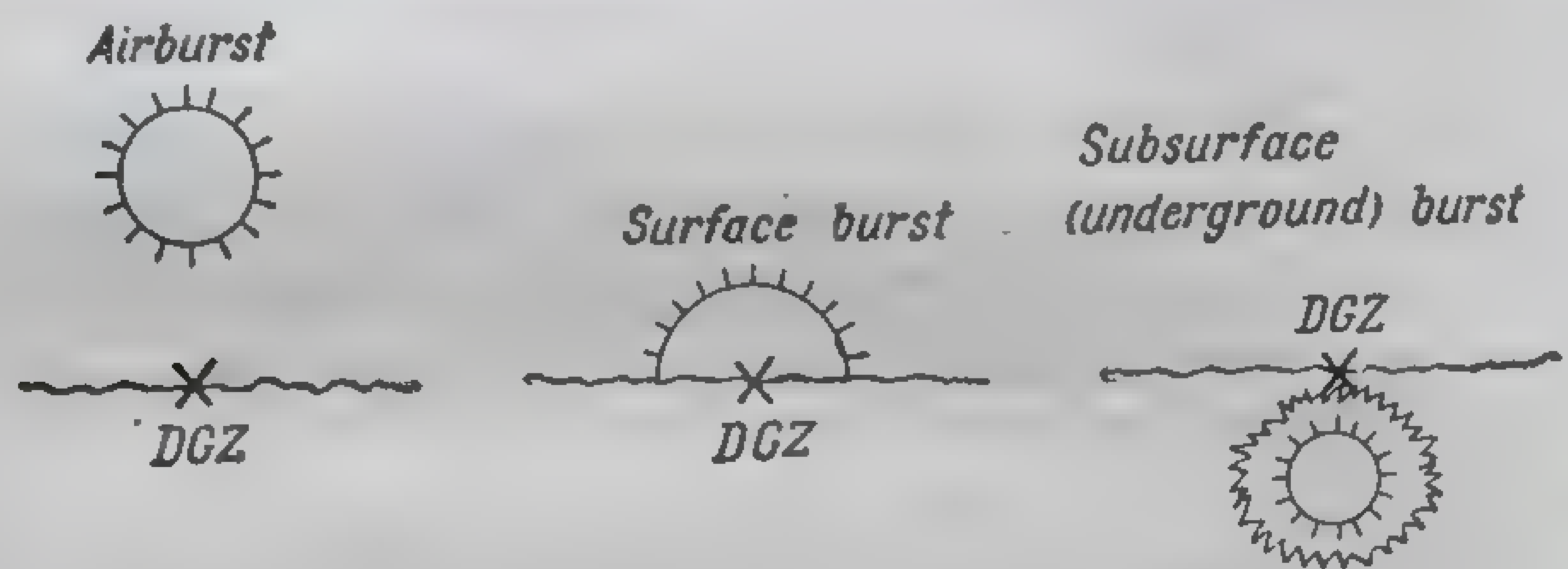

Fig. 33. Desired ground zero.

Time of Burst. The time of burst is determined by both tactical and technical considerations such as preinitiation, time for casualties, and maneuver plan. It is provided as a date time group. Example: 240830[1].

Estimated Results. The coverage of area targets or the probability of destroying a point target is always provided. The coverage for the primary target element will normally be described as an index number or a fraction. Example: .3/.4 for protected personnel. The .3 means there is a high (90 per cent) assurance of at least 30 per cent coverage from a single round; because the indexes have been rounded off to the nearest tenth, the .3 indicates a probable minimum coverage between .25 and .35. The .4 means that on the average a coverage of 40 per cent (between .35 and .45) can be expected. Additional information pertaining to the results of contingent effects in the target area is provided as part of the recommen-

[1] The 24th of the month; 08.30 hrs.

dation. This may be done by portraying graphically with a template the area of tree blowdown, fire hazard, and damage to various target elements.

Troop Safety. The distance to which the effects for negligible risk to unwarned exposed personnel extend is portrayed graphically to the commander. If this distance includes friendly troops, a graphic presentation is provided depicting the necessary risk and protection required.

TARGET ANALYSIS TERMS

Familiarity with the following terms and their definitions is important in gaining an understanding of the use of the WST:

— radius of damage (R_D). Radius of damage (or casualties) values are obtained from appropriate effects tables. Each degree of damage (severe, moderate, or light for materiel damage, and prompt or delayed for casualties) has its own R_D value for a specific target element and yield;

— radius of target (R_T). If the target is circular or nearly so R_T is the radius of the target circle. If the target is more nearly in the shape of an ellipse or rectangle the R_T is the radius of a circle which has the same area as the ellipse or rectangle. If the longest dimension of the target is equal to or greater than twice the shortest dimension, the target cannot be equated to a circle for the purpose of target analysis;

— horizontal error. The horizontal error of a weapon system is generally described in terms of circular error probable (CEP) or probable error (PE). As the probability charts or nomographs are constructed and based on CEP, noncircular errors, expressed as PE, must be converted to CEP;

— displacement distance (d). The symbol "d" represents the distance the desired ground zero or actual ground zero is located from the center of an area target or from a point target;

— variability (v). The symbol "v" indicates the variation in the response of similar targets to a given effect. Because of differences in orientation, construction, and stamina, no two items respond in exactly the same manner to a given weapon effect. This variation in tar-

get response, called variability, is already built into the probability charts, nomographs and selection tables to give a realistic damage distribution for tactical targets. For simplicity, only one variability (20 per cent) is considered in this text;

— fraction of damage (f). The symbol "f" represents the fraction or percentage of the total number of target elements which may be damaged or become casualties;

— probability of damage (p). The symbol "p" represents the probability or assurance of an event occurring successfully. In the case of area targets, it is the probability that a target will receive a specific fraction of damage. The probability of causing this damage is a function of the radius of damage (R_D), radius of the target (R_T), the horizontal error (CEP), and the distance the DGZ is displaced from the center of the target (d). In the case of point targets, it is assumed either they are or are not damaged. The probability of inflicting damage on the target is a function of the damage radius (R_D), the distance the DGZ is displaced from the target (d), and the horizontal error (CEP);

— assurance of fractional damage "P(f)". The symbol "P(f)" is an abbreviation which represents the assurance or probability of achieving at least a given fraction of damage to an area target with a single weapon attack. This symbol does not signify that "P" is multiplied by "f". In estimating damage or casualties within area targets, the target analyst deals in terms of probable minimum results when using the probability charts. In the employment of nuclear weapons, it is generally desired that there be a high probability (on the order of 90 per cent) of achieving at least a certain minimum fractional damage. This is referred to as the probable minimum coverage. This relates to a "one-shot probability" where some minimum level of damage can be counted on from a particular single-weapon attack. For example, a $P(f) = 0.90(0.40)$ indicates that there is a 90 per cent probability (assurance) of achieving at least a 40 per cent fraction of damage. Actually, more damage to the target may occur, but there is little likelihood of getting much less than 40 per cent;

— point targets. A point target may be either a single element type of target such as a bridge or a buil-

ding; or, it may be an area target whose radius is relatively small in comparison to the radius of damage (about 1 to 5). Examples of small area targets which are actually composed of a number of individual elements, but which may be treated as point targets, include command posts, a small, troop unit such as a platoon, or a small village;

— area targets. Larger targets which occupy a sizable portion of terrain are treated as area targets.

TECHNIQUES FOR TARGET ANALYSIS

General Procedure for Analyzing Targets. The following general procedural steps are those used by the target analyst. They serve only as a guide. Some steps may be omitted or changed in order to meet the needs of the experienced target analyst.

Each person who analyzes targets will normally develop a procedure which best fits his experience and ability:

— identify pertinent information;

— determine DGZ and height of burst option;

— eliminate obviously unsuitable weapons;

— determine and apply data for (1) estimating damage to the target; (2) troop safety considerations; (3) limiting requirements;

— eliminate unsuitable weapon systems;

— evaluate weapon systems and tactical situation;

— make recommendations.

Vulnerability Categories. For each weapon system and yield, tables are provided for four target vulnerability categories:

— exposed personnel (prompt and delayed casualties);

— protected personnel (prompt and delayed casualties);

— wheeled military vehicle materiel targets;

— tanks and artillery materiel targets.

Although these target vulnerability categories have been designated as the primary types of field army targets expected, they can be applied for most tactical yield weapons to other types of targets. In most cases, the accuracy of such application is consistent with target intel-

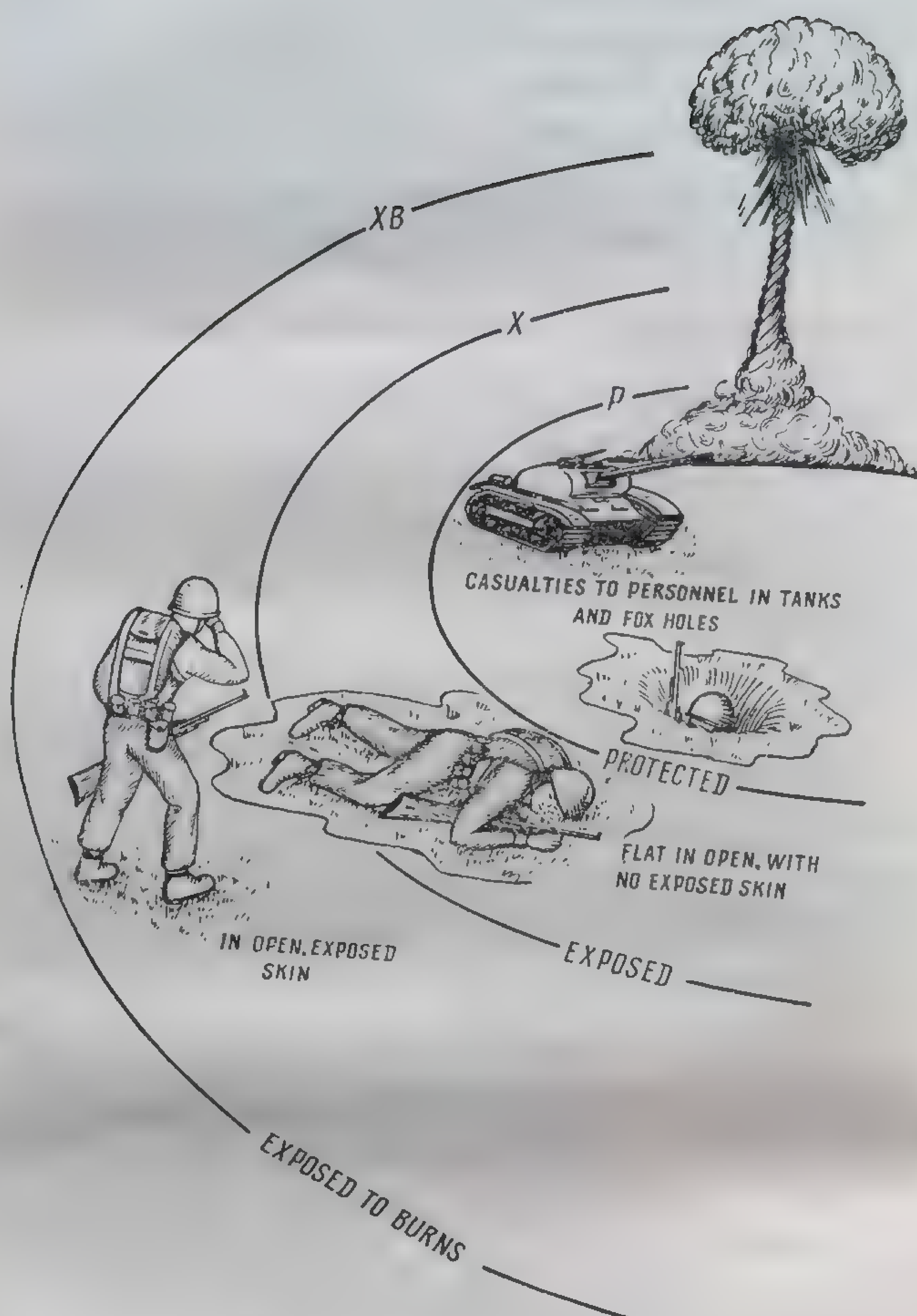

Fig. 34. Personnel casualty circle.

ligence and our knowledge of weapon effects. However, the casualty and damage tables may be consulted to determine which primary target element responds, near the desired HOB, in a manner similar to any target elements of interest.

SELECTION OF DESIRED GROUND ZERO

In predicting the damage resulting from the detonation of a nuclear weapon, or in predicting the effect of the burst on troop safety or limiting requirements, calculations are made with reference to the desired ground zero (DGZ). The selection of the DGZ is based on the results desired from the nuclear attack.

SELECTION OF HEIGHT OF BURST

Distance. The distance to which a given amount of thermal or nuclear radiation, or a stated blast overpressure will extend along the ground in a target area is dependent, to a considerable degree, on the height above the target at which the burst occurs.

The nuclear weapons employment officer recommends the proper height at which to burst a nuclear weapon. Generally, he will recommend to the commander only a height of burst option — high, low, or impact. When the delivery unit is given the fire order, the height of burst in meters may be required.

Surface Contamination. Of frequent concern in the selection of burst heights is the probability that surface contamination may occur. In the case of induced radiation, burst heights sufficiently high to minimize or eliminate this hazard usually reduce the damage effects of the weapon so markedly that there is little advantage in employing the weapon. In the case of fallout, however, burst heights can often be selected which will preclude fallout contamination, while an acceptable degree of damage or an acceptable number of casualties is produced.

Effects To Be Employed. Based on information of enemy dispositions and protection in the target area, and based upon the guidance as to damage required, the nuclear weapons employment officer must consider a height

of burst (or range of burst heights) for the weapon being investigated that will cause the desired effect on the target.

HEIGHT OF BURST OPTION

There are three height of burst options:

— low airburst. This HOB will normally produce greatest effectiveness while precluding fallout;

— high airburst. Lower effectiveness is accepted in order to reduce the intensity of induced contamination. Obviously, this height of burst will preclude fallout. This height of burst may occasionally increase damage to "soft" targets;

— impact burst. This burst option will cause cratering and will produce fallout. Normally, it will not be practical to deliver or emplace weapons deep enough to produce craters significantly larger than those produced by a surface burst unless existing mines or tunnels can be utilized for emplacement of the weapon.

Because the low airburst maximizes damage or casualties for most battlefield targets, and eliminates the problem of fallout, the low airburst is used in most cases. When the low airburst will not produce the desired damage against materiel targets, it may be desirable to lower the height of burst. This will increase the probability of significant fallout. The heights of burst shown in the low airburst coverage tables have been computed for a very high (99 per cent) assurance of no significant fallout. If the commander is willing to do so, lower assurances may be used to increase the probable minimum damage radius. When employing a weapon at a height of burst that provides less than a 99 per cent probability of no significant fallout, a fallout prediction must be made.

ELIMINATE OBVIOUSLY UNSUITABLE WEAPON SYSTEMS

The target analyst can save considerable time in performing target analyses by eliminating weapons from further consideration which will obviously not satisfy the requirements for attack of the target.

Weapon systems which do not have the range capability of engaging the target are eliminated. Targets

beyond the maximum range or below the minimum range of the weapon system cannot be engaged unless the delivery means can be displaced.

Weapons which are grossly too large or too small can be eliminated almost by inspection. When the weapon is not grossly too large or too small, it is retained for further consideration. Special tables assist in the elimination of weapons that are too small. They show the maximum target radii and maximum damage radii for each weapon system, yield, and target vulnerability category.

A weapon retained for further consideration is eliminated later when the target analysis determines it is not suitable.

EXPECTED COVERAGE FOR AREA TARGETS

Damage to the target may be estimated using any of the three methods. If the target is circular, nearly circular, or can be assumed circular, and he DGZ used is at target center, the index method is the most accurate and most meaningful to use. If the target is irregularly shaped, the visual method is used. In other cases, either the visual or numerical method may be used.

Unit SOP's (standing operating procedure) contain information regarding the extent of damage required for specific type targets. The guidance in the SOP will occasionally be modified by the commander. The following information may be used as a guide in developing the SOP;

— a destroyed unit is a unit that has been rendered completely ineffective. The unit will have lost command facilities, materiel, and many key personnel. The loss will be so extensive as to require withdrawal from action, complete reorganization, replacement of many personnel, resupply, and extensive retraining. Any casualties and damage caused by thermal effect and missile effect are considered bonus effects. Because these bonus effects contribute to the effectiveness of the attack, it is considered that coverage of one-third to one-half of a unit is generally sufficient to destroy the unit. Coverage in excess of one-half may be a waste of combat power

and may result in a subsequent shortage when a target appears that requires greater effects;

— a neutralized unit is a unit that has been rendered incapable of interfering with a particular tactical operation. The unit will have lost some key personnel, command facilities and materiel. The losses will be sufficiently extensive to require some local reorganization, improvisation of command and control facilities, minor repairs and limited resupply to make the unit combat effective. Effects such as missile effect, thermal effect, and damage to such elements as communication and supply systems are normally considered as bonus effects in the attack of troop units. Nevertheless, these bonus effects contribute to the effectiveness of a nuclear attack. For this reason, when casualties are predicted from blast or nuclear radiation in an area equal to 10 per cent of the area occupied by a unit, the unit is expected to be neutralized.

DAMAGE ESTIMATION

An estimate of the results to be achieved by a nuclear weapon attack is necessary in order to determine the optimum weapon for attack of that target. This estimate will also assist the commander in visualizing the condition of the target area after the attack. Obviously, the plan of maneuver may be different if 10 per cent of a target is expected to be destroyed as opposed to destruction of 50 per cent.

The estimation of the results to be achieved is usually expressed as a fraction or percentage of the target covered. If 30 per cent of the target is covered by the particular radius of damage, it is assumed that 30 per cent of the target elements of interest will receive the specified level of damage. The estimate of damage would be expressed as 30 per cent coverage of the target.

The standing operating procedure generally expresses the coverage desired by the commander in the attack of various type targets. When the situation is different from that assumed in establishing the SOP, the commander may modify the guidance for desired coverage.

— for most tacticai targets, it is desirable to select a weapon based on the estimate of personnel casualties

rather than damage to materiel. This is because most materiel targets are not as easily damaged as personnel. Furthermore, most units can be as effectively destroyed by loss of personnel as by loss of materiel;

— a probable minimum coverage of 30 per cent of a unit is generally sufficient to destroy the unit. Coverage in excess of 50 per cent may be a waste of combat power;

— a probable minimum coverage of 10 per cent of a unit is generally sufficient to neutralize the unit.

METHODS OF DAMAGE ESTIMATION

Depending on the characteristics of the target, there are three methods of estimating damage:

— index method;

— visual method;

— numerical method.

The index method is used to estimate damage to area targets when the target can be assumed to be circular, and the DGZ is at target center. The indexes in the coverage tables have been computed using a more precise method than can be used in the field.

The visual method is used to estimate damage to area targets when the target is not circular, or when the desired ground zero must be displaced from target center.

The numerical method is used to:

(a) Estimate the probability of damaging point targets.

(b) Determine the maximum distance that the DGZ may be displaced from a point target, or from the center of an area target.

(c) Determine the maximum allowable CEP for those systems with variable CEP's.

(d) Estimate damage to area targets. This method tends to indicate a degree of precision higher than that associated with the index method. This apparent precision is misleading because:

— the procedures used to calculate the combined coverage indexes are more precise than the numerical method;

— target input information for the numerical method is no more valid than the input for the index or visual methods.

INDEX METHOD OF DAMAGE ESTIMATION

In the body of the coverage tables (Fig. 35) [1] for each range and target radius, two decimal numbers are given separated by a slant mark (e. g., .3/.4). Taken together these numbers are an index of weapon effectiveness. The first number (.3) is the probable minimum fractional coverage of the target; the second number (.4) is the average coverage.

To determine the coverage index for the target being considered, the target analyst enters the appropriate coverage tables provided for each delivery system, yield, target category, and height of burst option.

(FOXTROT) 20-KT

Exposed Person

Large Free

Low Airburst

Range (meters)	Minimum safe distance (negligible risk UnW Ex) (meters)	Fraction of Tar In the column under each target radius the first the second figure is the							
		Prompt casualties							
		Target radius (meters)							
		800	1,000	1,200	1,400	1,600	1,800	2,000	2,200
7,000	6,000	.9/.9	.8/.9	.7/.8	.6/.6	.4/.5	.3/.4	.3/.3	.2/.3
8,000	6,000	.9/.9	.8/.9	.7/.8	.6/.6	.4/.5	.3/.4	.3/.3	.2/.3
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
23,000	6,300	.6/.9	.4/.8	.3/.7	.2/.5	.1/.4	.1/.4	.1/.3	.1/.2

Fig. 35. Sample coverage table for a

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[1] This and all succeeding tables represent extracts and serve to illustrate the concept. All parameters contained therein are hypothetical. Full tables with actual figures are furnished by corresponding troop manuals.

Fig. 35. shows part of a sample exposed personnel coverage table for a large free rocket (FOXTROT) 20-KT weapon, low airburst option. If the launcher-target range of the weapon is 23,000 meters and the target radius is 1,600 meters, the following indexes will result.

If the plan of maneuver requires prompt casualties, the 3,000 rad criterion is used; an index of .1/.4 results. If delayed casualties are acceptable, the 650 rad criterion is used; an index of .4/.5 results.

The estimate of damage in this case would be expressed as follows:

— 10 per cent probable minimum coverage and on the average 40 per cent coverage for prompt casualties among exposed personnel, or

— 40 per cent probable minimum coverage and on the average 50 per cent coverage for delayed casualties among exposed personnel.

nel Targets

Rocket

(Precludes fallout)

get Covered figure is the probable minimum coverage; average coverage								Probable minimum R_D (meters)		Offset distance d_o (meters)	Height of burst (meters)
Delayed casualties											
Target radius (meters)											
800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	Prompt	Delayed		
.9/.9	.8/.9	.5/.6	.3/.4	.2/.3	.1/.2	.1/.2	.1/.1	1,125	1,225	190	205
.9/.9	.8/.9	.5/.6	.3/.4	.2/.3	.1/.2	.1/.2	.1/.1	1,125	1,225	220	222
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
.8/.9	.6/.7	.4/.5	.2/.3	.1/.2	.1/.2	.1/.1	—	700	1,050	625	485

large free rocket (Foxtrot) 20-KT

The visual method of damage estimation consists of a visualization of the fraction of the target covered by the radius of damage.

Circular Map Scale. The circular map scale is a series of concentric circles and arcs drawn at regular in-

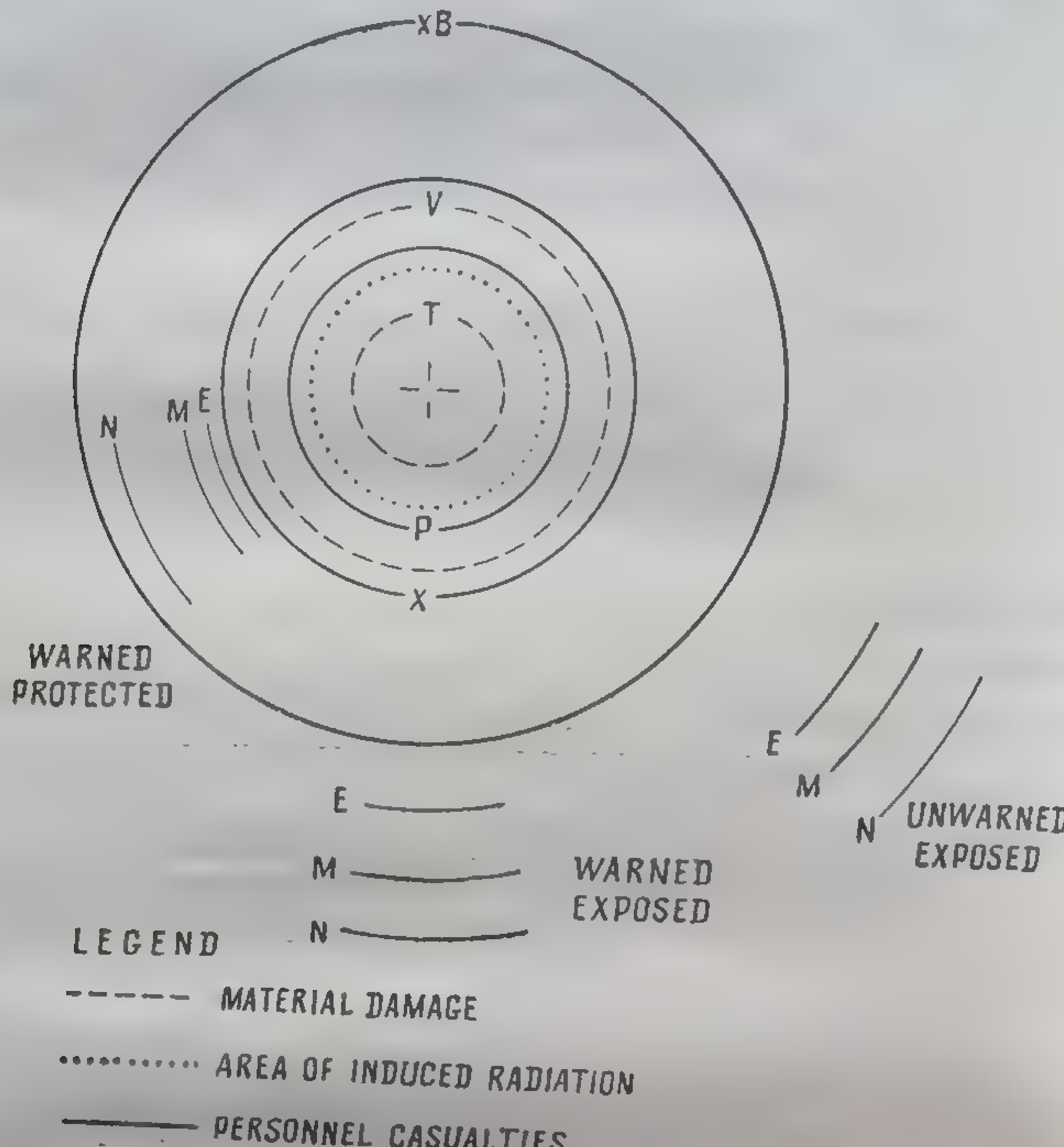

Fig. 36. Visual estimate of target coverage.

tervals on transparent material. The interval between the circles and arcs for a 1 : 50,000 scale is 100 meters out to 1,000 meters from the center, then 200 meters. For the 1 : 100,000 scale the interval is 200 meters out to 2,000 meters, then 400 meters. Visual interpolation can be made when the distance of interest lies between the circles or arcs. The numbers on the circles and arcs represent hundreds of meters.

Radius of Damage. The radius of damage is determined from the coverage tables in the same manner as the coverage index. The target analyst enters the appropriate coverage tables using the appropriate range.

Continuing the example shown above (large free rocket /FOXTROT/20-KT, range 23,000 meters), the following extract of Fig. 35 results.

If prompt casualties are desired, the 3,000 rad criterion is used; the probable minimum R_D is 700 meters. If delayed casualties are acceptable, the 650 rad criterion is used; the probable minimum R_D is 1,050 meters.

Offset Distance. The offset (d_0) is shown on each page of coverage tables. The offset distance for the example shown in Fig. 35 is 625 meters.

There is a high assurance (90 per cent) of a round bursting within the distance, d_0, of the DGZ.

NUMERICAL METHOD OF DAMAGE ESTIMATION

The numerical method involves the use of charts and nomographs in conjunction with effects data to provide a numerical description of the damage which a particular nuclear weapon with given delivery errors will inflict upon a particular target. It is amenable to give an estimation of damage to circular targets of any size, with weapons of any yield, and different burst heights or damage criteria. It is particularly suitable for analysis of point targets and for determining the maximum CEP and maximum displacement distance that will give the desired results. However, the analyst must not become so impressed with the apparent precision and completeness of a numerical target analysis that he is not cognizant of its shortcomings. The analyst must recognize the weaknesses in his tools, methods, and input data. In general, the probabilities of fractional coverages derived from the numerical method are conservative because compound probabilities are not considered.

PROBABILITY OF DESTROYING POINT TARGETS

For target analysis purposes, any target with a radius less than one-fifth the radius of damage is considered a point target. Fractional coverage of a point target has no meaning; the target is so small that the target will be completely covered or completely missed by the

radius of damage. Estimation of the damage to point targets, therefore, consists of determining the probability of the target receiving the desired degree of damage rather than estimating the fraction of the target to be covered. The probability of destroying a point target is a function of initial weapon effects and delivery error. The probability of destroying a point target is determined using the numerical method.

TROOP SAFETY

When compared with the use of nonnuclear weapons, the use of nuclear weapons in close tactical support involves a much greater degree of risk to the safety of friendly troops.

Troop safety may influence the selection of yield, delivery system, DGZ, time of burst, and scheme of maneuver.

The nuclear weapons employment officer uses a minimum safe distance (MSD) to make troop safety calculations. The MSD considers both delivery error and the distance to which certain weapon effects extend. The following definitions are used in determining the appropriate MSD.

There are three degrees of risk associated with troop safety considerations — negligible, moderate, and emergency.

At a negligible risk distance, troops are completely safe, with the possible exception of a temporary loss of night vision or dazzle. A negligible risk is acceptable in any case when the use of nuclear weapons is desirable. Negligible risk should not be exceeded unless significant advantages will be gained.

At a moderate risk distance, anticipated effects levels are tolerable, or at worst a minor nuisance. In rare instances some individuals may require evacuation because of radiation sickness, particularly if they have been exposed frequently to radiation. Moderate risk is considered acceptable in close support operations; for example, to create a gap in enemy forward positions or to halt an enemy attack. A moderate risk should not be exceeded if the troop units are expected to operate at essentially full efficiency after the burst.

At an emergency risk distance, the anticipated effects levels may cause some temporary shock and

a few casualties. A number of long-term casualties may be produced if personnel have been previously exposed to nuclear radiation. Personnel may be knocked temporarily unconscious from the blast wave. Collapsing foxholes may cause some casualties. For these reasons, there may be a significant short-term or long-term decrease in the combat efficiency of the unit. An emergency risk should be accepted only when absolutely necessary and should be exceeded only in extremely rare situations.

Closely associated with the degree of risk is the vulnerability of the individual soldier. The danger to an individual from a nuclear explosion depends principally upon the degree to which he is protected from the weapon effects. For example, a man who is well protected can safely be much closer to ground zero than can a man in the open. The degree of protection of the individual is considered in target analysis to be dependent upon the amount of advance warning the individual has received. One or more of the following three conditions of personnel vulnerability can be expected at the time of burst: unwarned, exposed; warned, exposed; and warned, protected.

Unwarned, exposed persons are assumed to be standing in the open at burst time, but have dropped to a prone position by the time the blast wave arrives. They are expected to have areas of bare skin exposed to direct thermal radiation, and some personnel may suffer temporary dazzle. For example, such a condition can be expected to prevail in an offensive situation when the majority of the attacking infantry are in the open, and a warning of the burst has not been disseminated.

Warned, exposed persons are assumed to be prone on open ground, with all skin areas covered, and with an overall thermal protection at least equal to that provided by a two-layer summer uniform. For example, such a condition may prevail when a nuclear weapon is employed against a target of opportunity during an attack and sufficient time exists to broadcast a warning; troops have been warned, but do not have time to dig foxholes.

Warned, protected persons are assumed to have some protection against heat, blast, and radiation. The assumed degree of protection is that protection offered to personnel who are in "buttoned-up" tanks or crouched in foxholes with improvised overhead thermal shield-

ing. When only a lesser degree of protection is available, e. g., only armored carriers are available, personnel cannot be considered to be warned, protected. The target analyst would consider such personnel as exposed. A warned, protected condition is generally expected to prevail when nuclear weapons are used in a preparation prior to an attack.

Note that there is no category for unwarned, protected. Although protection may be available to personnel, it cannot be assumed that they will be taking advantage of it unless they are warned of an impending burst. Procedures for warning friendly personnel are discussed further on.

For each combination of degree of risk and condition of personnel vulnerability, there is an associated "risk distance" known as the radius of safety. It is the horizontal distance from the actual ground zero beyond which the weapon effects are acceptable. Because a round may burst at the end of the dispersion pattern nearest to friendly troops, a buffer distance is added to the radius of safety. The buffer distance provides a very high assurance (99 per cent) that unacceptable weapon effects will not reach friendly troops. The size of the buffer distance is dependent on the horizontal delivery error at the applicable range. The sum of the radius of safety and the buffer distance is the minimum safe distance (MSD). The MSD value for negligible risk to unwarned, exposed personnel is found on each coverage table. If troops are further away than this distance when the delivery unit is firing perpendicular to the straight line forward dispositions, there is no troop safety problem. If other risk and/or vulnerability conditions are applicable and the distance from the DGZ to friendly troops is less than that indicated for negligible risk to unwarned, exposed personnel in the coverage tables, the target analyst refers to other troop safety tables, which provide appropriate MSD's. There is also a correction table for the MSD's when troops are disposed in other configurations with respect to the gun target line.

In determining the degree of risk to which troops will be exposed, the target analyst needs to know the location of friendly elements, and degree of protection they are expected to have at the time of burst. The nuclear safety line, may present this information to the target analyst.

The following procedure is used to check that troop safety requirements are met when airbursts are being employed:

(1) The negligible risk distance for unwarned exposed troops is shown on each page of the coverage tables. Continuing the example provided above and extracting from Fig. 35, Fig. 37 results.

Range	Minimum safe distance
(meters)	risk, UnW Ex (meters)
23,000	6,300

Fig. 37. Minimum safe distance.

(2) In this case, the minimum safe distance (MSD) is 6,300 meters. Except as indicated in (5) below, if this distance is less than the distance separating the DGZ and the nearest friendly troops, there is no troop safety problem. Fig. 38 shows this situation.

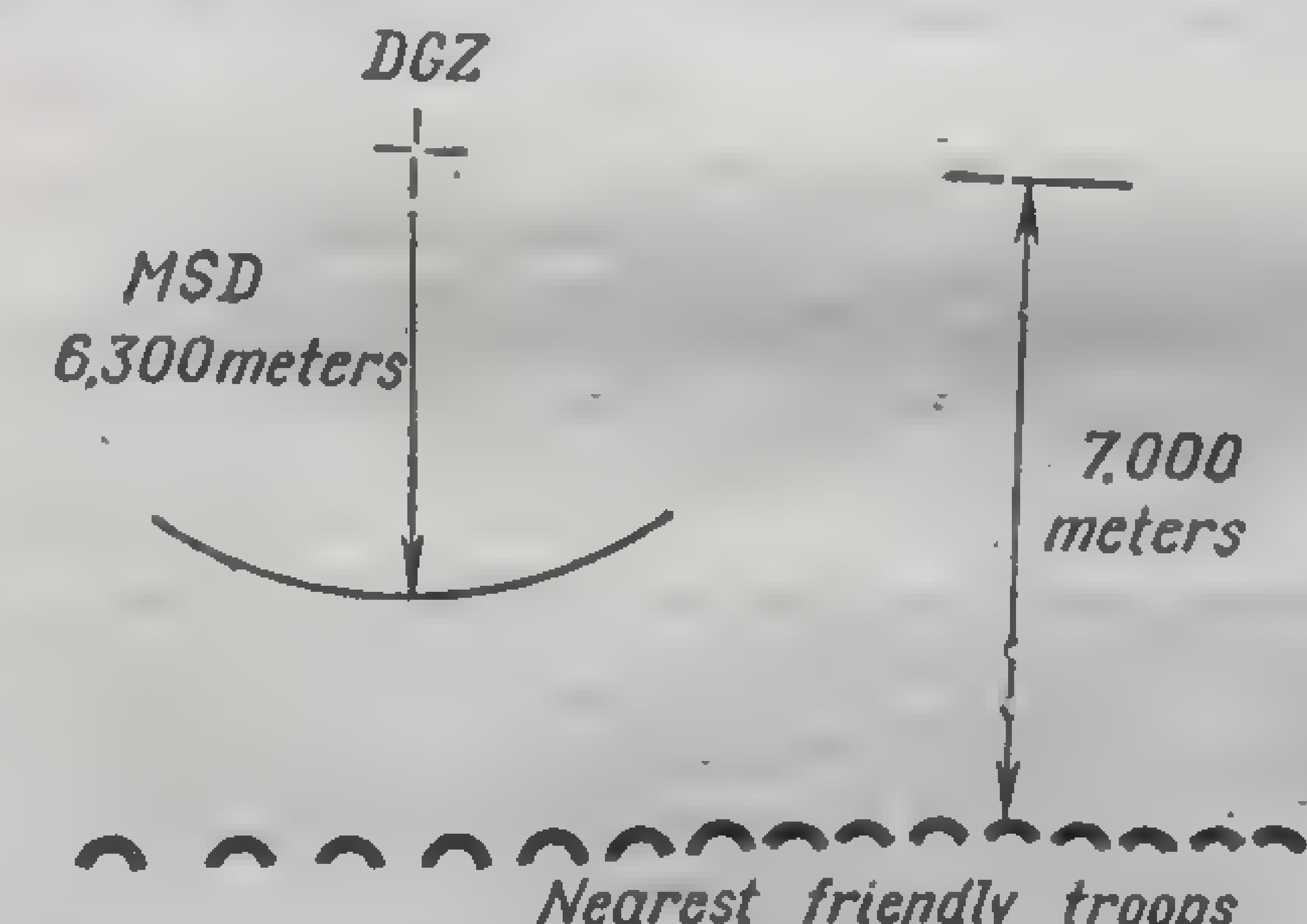

Fig. 38. Troop safety.

(3) A set of basic troop safety tables is provided for each yield and weapon system. These tables show the MSD's for each degree of risk and each condition of troop vulnerability. Fig. 39 shows part of a sample basic troop

safety table for a large free rocket (FOXTROT) 20-KT weapon, low airburst.

(FOXTROT) 20-KT

Troop Safety Distances — Meters

Large Free Rocket

Low Airburst

Range (meters)	Minimum Distance Required for Troop Vulnerability and Degree of Risk Shown								
	Unwarned Exposed Personnel			Warned Exposed Personnel			Warned Protected Personnel		
	NEG Risk	MOD Risk	EMERG Risk	NEG Risk	MOD Risk	EMERG Risk	NEG Risk	MOD Risk	EMERG Risk
7,000	6,000	4,200	3,700	3,700	2,500	2,000	2,100	1,800	1,500
8,000	6,000	4,200	3,700	3,700	2,500	2,000	2,200	1,800	1,500
9,000	6,100	4,200	3,700	3,800	2,500	2,000	2,200	1,800	1,500
10,000	6,100	4,200	3,700	3,800	2,500	2,000	2,300	1,800	1,500
21,000	6,300	4,400	3,900	4,000	2,700	2,200	2,900	2,200	1,700
22,000	6,300	4,500	3,900	4,000	2,700	2,200	3,000	2,200	1,700
23,000	6,300	4,500	3,900	4,000	2,700	2,300	3,000	2,200	1,800
24,000	6,300	4,500	4,000	4,000	2,700	2,300	3,100	2,200	1,800
25,000	6,300	4,500	4,000	4,000	2,800	2,300	3,100	2,300	1,800

Fig. 39. Sample basic troop safety table

All Heights of Burst Options — All Yields

Range (meters)	Straight-line parallel delivery	Straight-line 45° delivery	Quarter circle	Half circle
7,000	+200	+100	+200	+200
8,000	+200	+100	+200	+200
9,000	+200	+100	+200	+200
10,000	+200	+100	+200	+200

Fig. 40. Sample supplementary troop safety table.

(4) Assume that the situation depicted in Fig. 38 had indicated that the nearest friendly troops were 5,500 meters from DGZ instead of 7,000. Troop safety is now a consideration:

— unwarned, exposed personnel closer than 6,300 meters is exposed to more than a negligible risk. They will be exposed to less than a moderate risk. (MSD for moderate risk is 4,500 meters.);

— if there is sufficient time to warn personnel, warned exposed personnel beyond 4,000 meters will be exposed to only negligible risk;

— if personnel are to be exposed to a greater than negligible risk, the commander must be so informed. If time must be taken to warn personnel, the commander must again be informed;

— troops are warned in accordance with SOP;

— if an increase in risk is unacceptable, or if there is insufficient time to warn personnel, the DGZ must be displaced further from the nearest friendly troops. In such a case, a new estimate of the damage must be made.

(5) A set of supplementary troop safety tables has been provided for each weapon system. These tables show the correction factors which must be applied to the MSD when the friendly troop orientation is other than straight line and perpendicular to the direction of fire. Fig. 40 shows a supplementary troop safety table for the large free rocket (FOXTROT) 20-KT weapon.

FALLOUT PREDICTION

When surface bursts are employed, the fallout hazard will dictate the MSD.

The shape of prediction area is shown in Fig. 41.

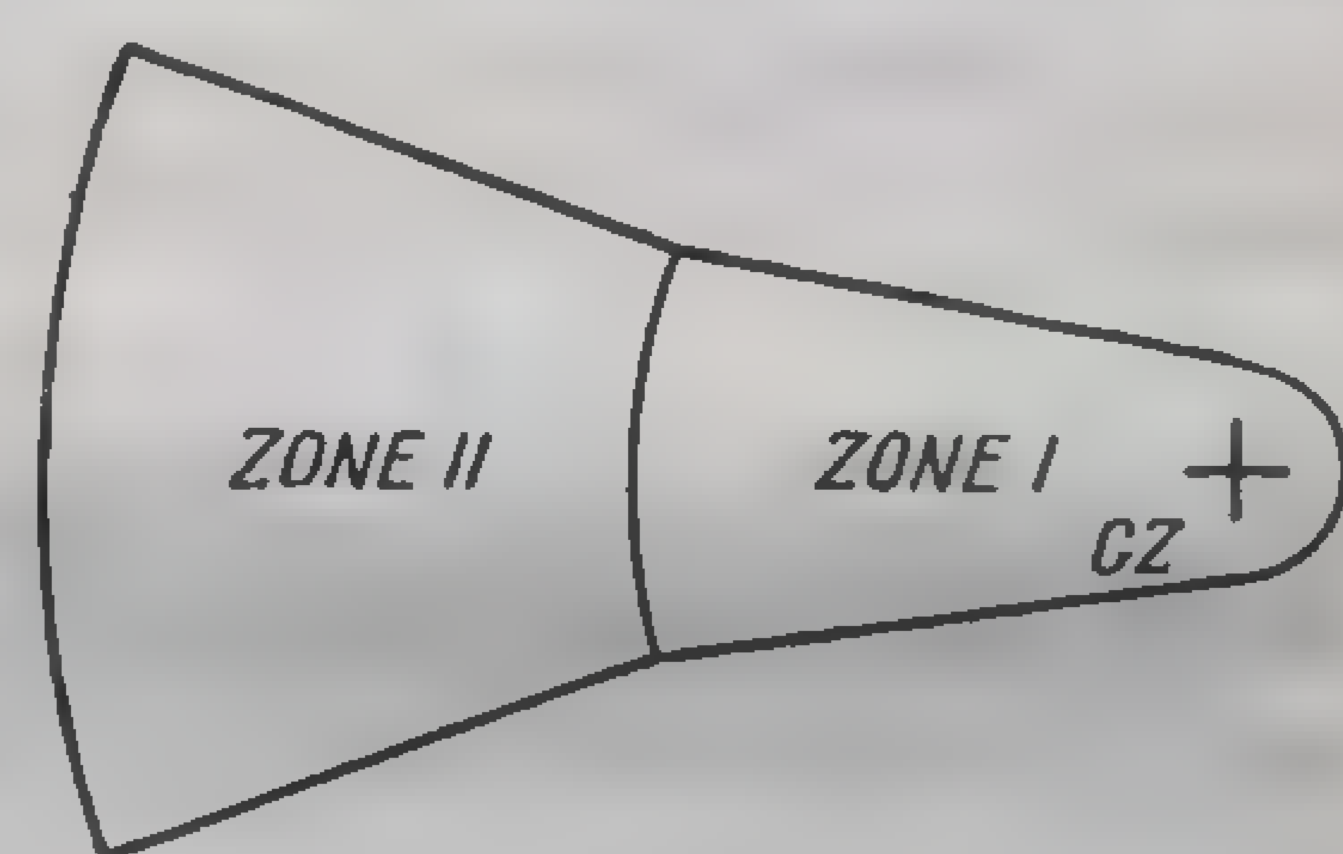

Fig. 41. Fallout prediction.

Zone I in Fig. 41 is an area within which there will be areas where unprotected personnel may receive casualty-producing doses (greater than 100 rad) in relatively short periods of time (less than 4 hours after actual onset of fallout).

Zone II delineates an area within which unprotected personnel are not expected to receive a total dose of more than 100 rad when remaining in the area for not more than 4 hours after actual onset of fallout.

Outside zones I and II, it is anticipated that unprotected personnel will receive a total dose that does not exceed 20 rad in the first 6 hours after actual onset of fallout. The total does for an infinite stay outside zones I and II should not exceed 150 rad.

In making fallout predictions in friendly held terrain, there is a reasonably high assurance that the fallout doses in zones I and II will not exceed those specified above.

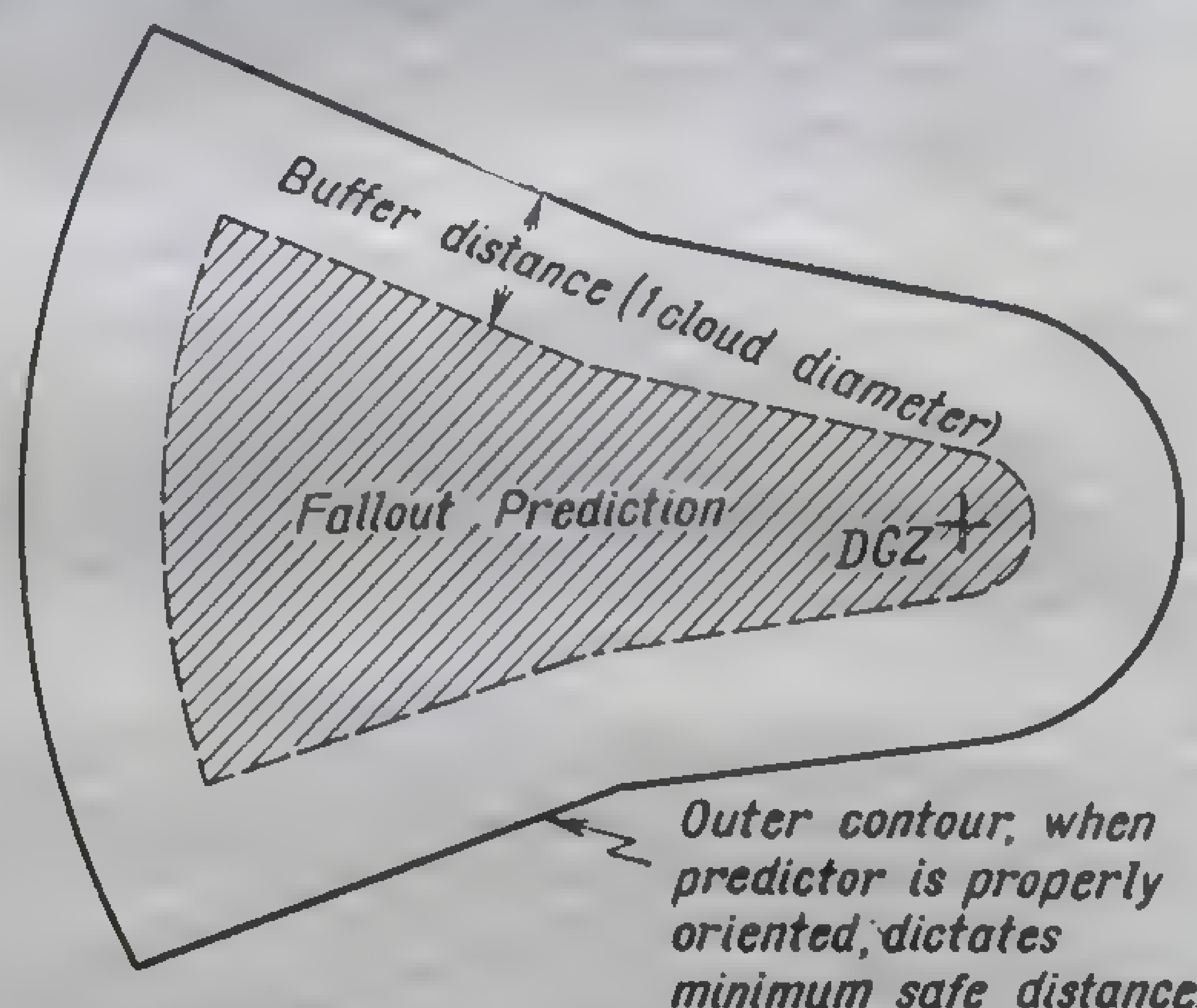

Fig. 42. Troop safety distance.

When making a fallout prediction in enemy held terrain, meteorological data are likely to be less accurate. In order to increase the assurance of avoiding damage to friendly elements from friendly weapons, a buffer distance is added around the fallout prediction area. This buffer distance is equal to the cloud diameter (cloud radii are provided in special tables). The buffer distance is illustrated in Fig. 42.

CONTINGENT AND BONUS EFFECTS

Contingent Effects. The coverage tables are computed using the governing effect — that effect which extends the greatest distance to cause the desired degree of damage to the principal target element. Contingent effects are effects other than the governing effect. They are divided into

bonus effects which are desirable, and limiting effects that are undesirable.

Bonus Effects. When a nuclear weapon is used on a target there will be many effects other than the governing effect which will assist in the destruction of enemy elements. These are termed "bonus effects." Some are predictable, others are not. The desirability of achieving bonus effects on the primary target element or on another target element may influence the selection of a nuclear weapon. The target analyst checks to see whether a predictable bonus effect may exist at a certain point by obtaining the radius of damage for the effect from the casualty and damage tables. He then estimates the effect on the target by considering the effect of horizontal dispersion.

Limiting Requirements. Restrictions placed on the employment of nuclear weapons are referred to as "limiting requirements." These limiting requirements are imposed to avoid the undesirable effects caused by nuclear weapons. These undesirable effects usually take the form of:

— creation of obstacles to the movement of friendly troops;

— damage to installations desired for the use of friendly troops, such as bridges.

The distance to which obstacle-producing effects extend is extremely variable. Such effects as induced contamination, fallout, tree blowdown, fires, and rubble are influenced drastically by such factors as terrain, soil types, and construction materials. Because of the lack of precise data concerning the distance to which these effects extend, vertical dispersion is not considered in estimating their impact on operatons.

Contingent effects tables are shown in the selection tables.

EVALUATION OF WEAPON SYSTEMS AND TACTICAL SITUATION

Considering one target at a time, the weapon systems are listed in priority based on their relative capability and suitability for attack of the target. All suitable weapon systems considered are listed for each target.

Based on such factors as the tactical situation, alloca-

tions, mission, target priorities, and system reliabilities, one weapon is selected for attack of each target.

The selection discussed above forms the basis for a recommendation to the commander. The information to be included in the recommendations has already been discussed.

ANALYSIS OF FRIENDLY DISPOSITIONS AND INSTALLATIONS

The circular map scale, in conjunction with effects data obtained from the vulnerability radii (R_v) table is used to predict the results of an assumed enemy nuclear attack of friendly dispositions or installations in the following manner:

Step 1. Determine the appropriate yield. Based upon current intelligence or the enemy's past use of nuclear weapons, the intelligence officer assumes a weapon yield that the enemy is likely to use against friendly dispositions or installations.

Step 2. Determine degree of exposure of friendly units. The assumed conditions of exposure of friendly troops is provided by the G3 (G4 for logistical installations).[1]

Step 3. Determine appropriate radii. Obtain appropriate vulnerability radii from the R_v table[2] and mark these radii on the circular map scale.

Step 4. Estimate results of enemy nuclear attack. Apply the circular map scale to the map representation of the disposition or installation to be analyzed. Place the centre of the circular map scale over the center of the greaterst concentration. With the aid of the labeled circles, estimate the area within which casualties may occur, or within which materiel damage will probably occur if the ground zero were at this location. The ground zero for this type of analysis is selected, on a "worst case" basis, as the point which would result in the greatest loss to friendly forces. Note that this is the procedure used for estimating damage to targets using the visual method. Delivery errors are neglected in this type of analysis.

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[1] G-3 — operations and training section; G-4 — logistics.

[2] Radius of vulnerability tables are supplied with other weapons Selection Tables by corresponding manuals.

The personnel radii in the R_v table are the emergency risk radii of safety (R_S) for various vulnerability conditions. The emergency risk R_S distance is used as the R_v because, at that distance, a few casualties are expected. Inside the emergency risk distance, casualty percentages increase rapidly as the distance to ground zero decreases. Therefore, the use of the emergency risk R_S distance as the friendly personnel vulnerability radius is considered valid. From the foregoing discussion, it can be seen that R_v for personnel does not have the same meaning as R_D.

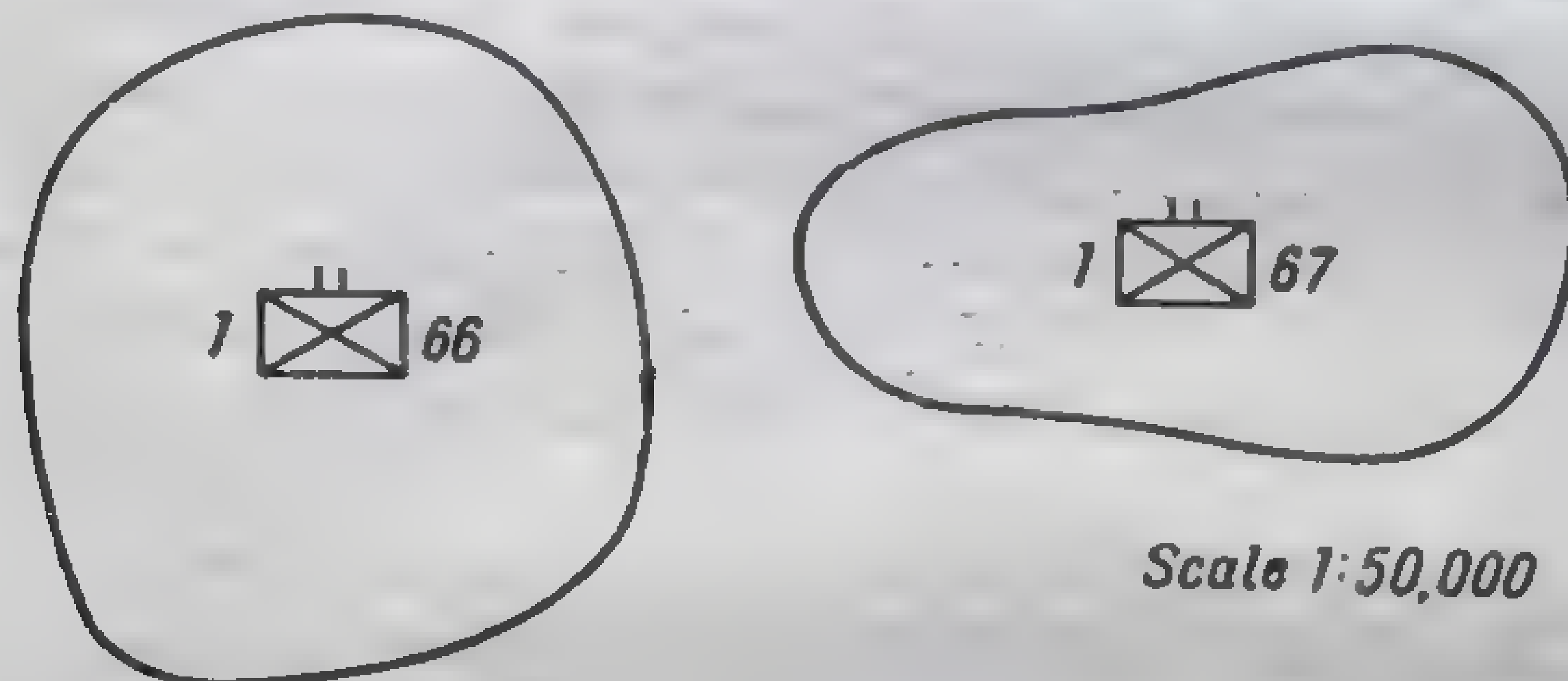

Fig. 43. Vulnerability analysis.

The assumption is made that essentially all personnel within an R_D will become casualties. As indicated above, personnel within the R_v may become casualties; many personnel will not become casualties. An example of the difference is illustrated when nuclear radiation criteria are considered. R_D's are based on 3,000 and 650 rad, while R_v's are based on 100 rad.

Radii for damage to materiel included in the R_v table were obtained from the casualty and damage tables. The maximum R_D in the column of interest is used as the R_v.

DETERMINING VULNERABILITY TO NUCLEAR ATTACK

Example. The 1st Bn, 66th Inf, and 1st Bn, 67th Inf, part of the 1st Bde, occupy reserve areas as shown in Fig. 43. The SOP requires that analysis be made of these positions to determine their vulnerability to nuclear attack.

Step 1. Determine the appropriate yield. Based on the current intelligence available, and an analysis of the proximity of enemy forward elements, the G2[1] estimates

[1] G-2 — Intelligence section.

that a 20-KT weapon is the largest weapon that the enemy is likely to use against these units.

Step 2. Determine degree of exposure of friendly units. All personnel of both units have foxhole protection. The G3 estimates that many personnel will be in the open at any given time. An appropriate assumption is that those friendly troops in the open will have some bare skin exposed.

Step 3. Obtain appropriate vulnerability radii. Refer to the R_v table. On the 20-KT line, read for troops in the open, no thermal protection, the $R_v = 3{,}500$ meters. For troops in foxholes, the $R_v = 1{,}325$ meters. Mark and label these radii on the 1 : 50,000 scale circular map scale.

Step 4. Estimate results of enemy nuclear attack. With the centre of the circular map scale over the centre of 1st Bn, 66th Inf position, the R_v for troops in the open without thermal protection extends well beyond the limits of the position (in fact, well into the area of 1st Bn, 67th Inf). All of the exposed personnel may be casualties. The R_v circle for troops in foxholes covers nearly all of the area; therefore, it is estimated that nearly all of the protected personnel may become casualties. The final estimate concludes that practically all of the personnel of the 1st Bn, 66th Inf and about one-third of the exposed (without thermal protection) personnel in the 1st Bn, 67th Inf may become casualties if a 20-KT weapon is burst over the centre of the 1st Bn, 66th Inf. The analysis of the 1st Bn, 67th Inf, is made in the same manner.

When analyzing two units as shown in Fig. 43 a GZ between the two units is also assumed. Placing the circular map scale between the two units shows that essentially all of the exposed personnel in both units may become casualties. About one-fourth of the protected personnel in each unit may become casualties. A GZ between these two units, then, is the "worst case" GZ.

TACTICAL CONSIDERATIONS

Time of Attack. A set rule for selecting the time for firing a nuclear preparation should not be made. In order to achieve surprise, it may be desirable to fire all weapons at the same time or as close together as possible. Because well-trained troops will become prone as soon as they ob-

serve the flash of the first burst, surprise may often be achieved by delaying the delivery of subsequent rounds. Sometimes better results may be obtained by firing on targets at irregular time intervals. Weapons supporting a secondary attack may be fired first to assist in locating reserves or to cause the premature commitment of the enemy's reserve.

Time for Tactical Damage Assessment. When a less reliable weapon system is employed a backup weapon if available is placed in an on-call status. In planning the nuclear attack, time should be allowed for making a tactical damage assessment of the first round to determine whether the backup weapon should be fired. The time interval will vary depending on such factors as communications, visibility, and the maneuver plan.

Preinitiation Considerations. The radiation from one nuclear weapon may cause a subsequent weapon to be detonated prematurely. Such an occurrence is called "preinitiation." No preinitiation problem will arise if the ground zeros are at least 10,000 meters apart.

ILLUSTRATIVE PROBLEMS

Example 1:

Given:

— the target shown in Fig. 44 consists of protected personnel;

— the nearest friendly troops are 4,000 meters from target centre.

Find: Recommendations for attack of the target.

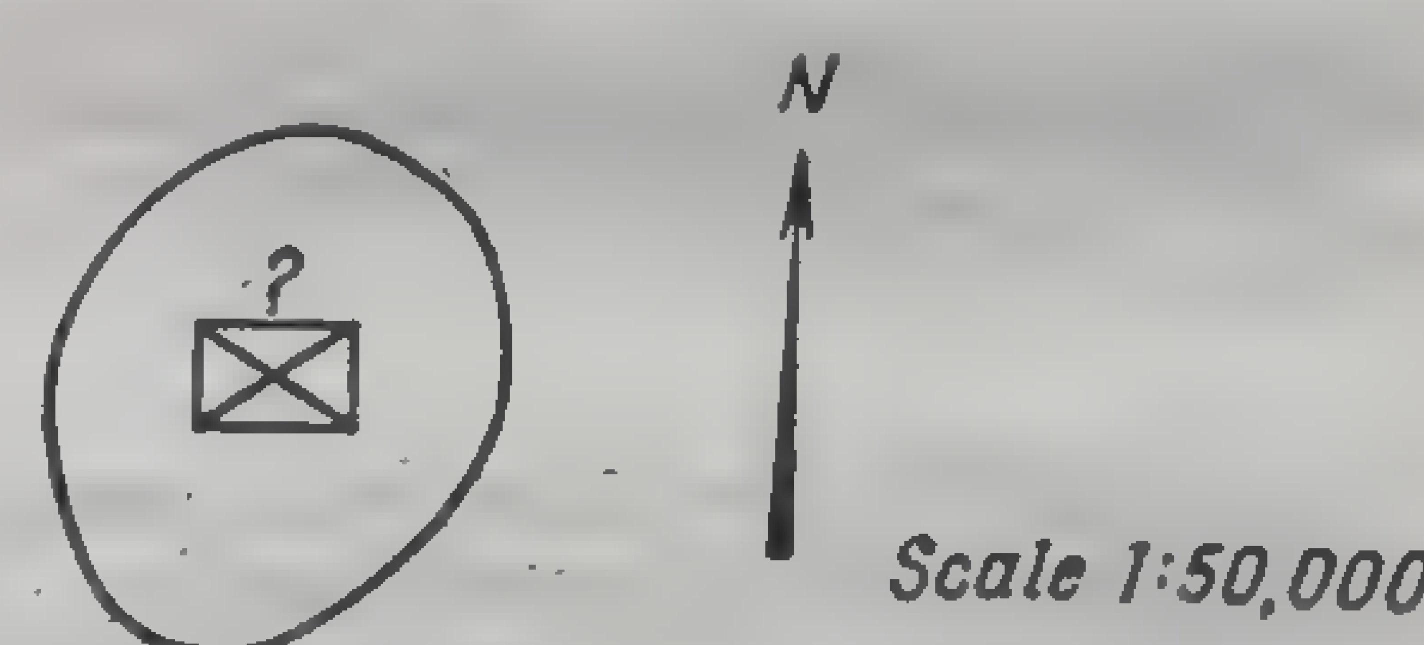

Fig. 44. Dug-in unit.

Solution:

Step 1. Identify pertinent information. (The information presented below is the type of information expected to be available to the NWEO. Sources would include the SOP, the G3 element of the field staff and the fire capabilities overlay).

1. The SOP indicates that 30 per cent coverage of a target is normally desired.

2. The scheme of maneuver is such that delayed casualties are acceptable.

3. The target radius is measured as 800 meters.

4. The SOP requires that the commander be informed when negligible risk to unwarned exposed personnel must be exceeded.

5. The commander has been allocated a short range cannon (BRAVO) 1-KT weapon.

6. A short range cannon unit is 9,000 meters from target centre. A (BRAVO) 1-KT weapon is available at the unit.

7. All necessary staff and delivery unit actions can be accomplished by 060930 hours.

8. The only trees in the area are type II [1].

The soil most closely approximates type II.

Step 2. Determine DGZ and height of burst option.

1. DGZ is tentatively selected at target centre, because there is no apparent reason to displace the DGZ.

2. A low airburst is chosen to give greatest effectiveness. A high airburst would decrease the effectiveness. There is no impact fuzing capability with this delivery system.

Step 3. Eliminate obviously unsuitable weapons. Only one weapon is available. It cannot be eliminated at this time.

Step 4. Determine and apply data for—

1. Estimating damage to the target. Since this target is generally circular, and the DGZ is at target center, the index method is appropriate. Enter figure 1.25. For a short range cannon (BRAVO) 1-KT, low airburst, range 9,000 meters, delayed casualties, target radius 800 meters, the combined coverage index is .4/.5. Reference to figure 13.9 indicates that this is a normally suitable index.

2. Troop safety considerations. The negligible risk distance for unwarned, exposed personnel is 1,900 meters, this is less than the distance from the DGZ to the nearest friendly troops (4,000 meters). Troop safety is not a consideration in this case.

3. Limiting requirements. Not a consideration in this case.

---

[1] Coverage tables show damage to three types of forests and soils. Each type is likened to one of the areas of the USA.

S t e p 5. Eliminate unsuitable weapon systems. The system under consideration meets all of the stated requirements and should not be eliminated.

S t e p 6. Evaluate weapon systems and tactical situation. Only one weapon and one target are being considered in this case. Normally, however, the recommendations must consider this target in relation to other targets that may develop.

S t e p 7. Make recommendations.

1. The following recommendations are made by the nuclear weapons employment officer:

— weapon system — short range cannon (BRAVO) 1-KT,

— height of burst option — low air (the mission to the unit would indicate HOB = 109 meters);

— DGZ — coordinates of target center;

— time of burst — 060930;

— estimated results — 40 per cent probable minimum coverage and on the average 50 per cent coverage for delayed casualties among protected personnel;

— troop safety — negligible risk to unwarned, exposed personnel. Warn aircraft.

2. If there is sufficient time to do so, all personnel should be warned to the limit of visibility.

3. The recommendations include a graphic portrayal on a circular map scale of the following radii:

— tree blowdown obstacles to foot movement, type II forests, 400 meters [1];

— second degree burns on bare skin, 750 meters [1];

— safety radii for fixed wing aircraft, 5,000 meters [1];

— 2 rad/hr contour type II soil, 300 to 600 meters [1].

E x a m p l e 2:

Given:

— the target shown in Fig. 45 consists of protected personnel;

— the nearest friendly troops are 4,000 meters south of target centre;

— the trees along Highway 10 are type III;

— the soil is the area most closely approximates type III soil.

Find: Recommendations for attack of the target.

---

[1] Obtained from appropriate tables, not included in this book.

Solution:

Step 1. Identify pertinent information. (The information presented below is the type of information expected to be available to the NWEO. Sources would include the SOP, the G3 element of the operational staff and the fire capabilities overlay).

1. The SOP indicates that 30 per cent coverage of a target is normally desired.

2. The scheme of maneuver is such that delayed casualties are acceptable.

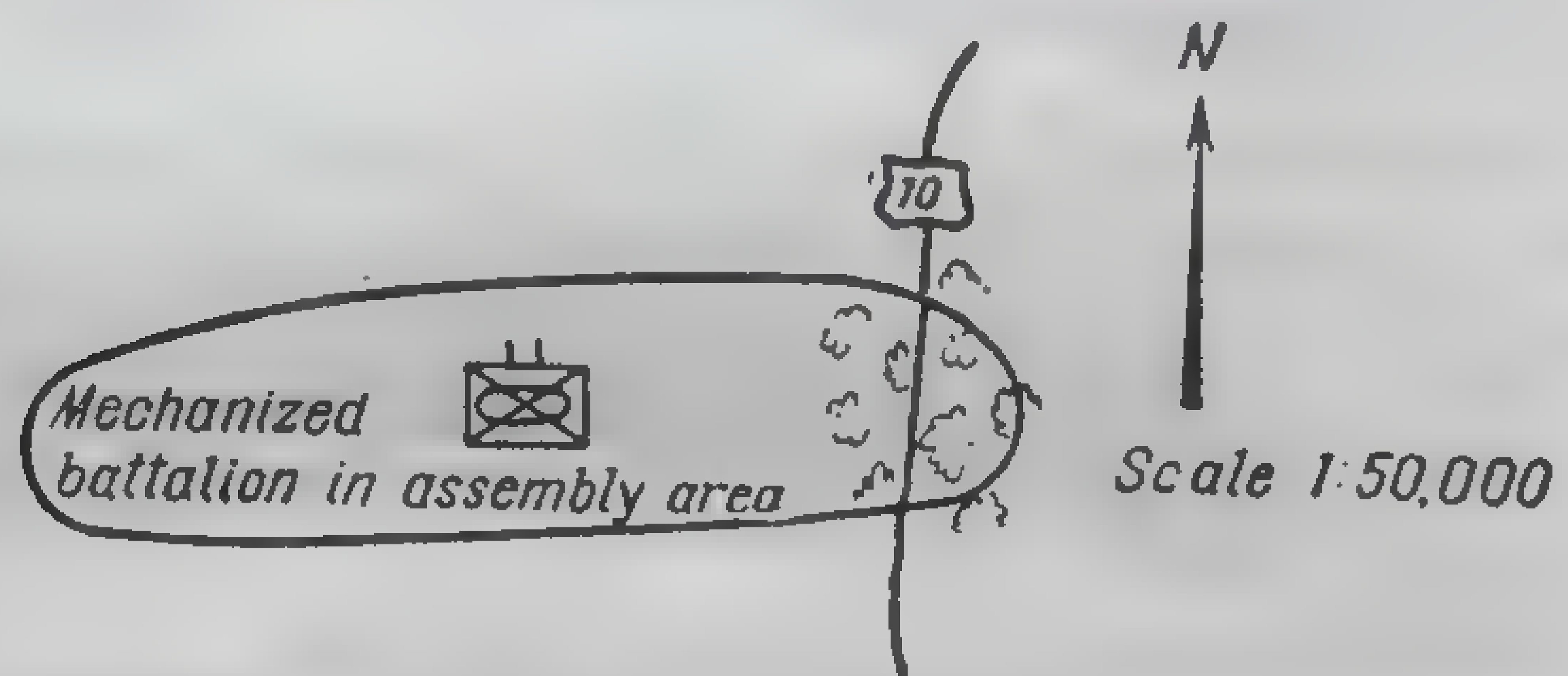

Fig. 45. Mechanized rifle battalion.

3. The SOP requires that the commander be informed when negligible risk to unwarned, exposed personnel must be exceeded.

4. The commander has been allocated a long range cannon (ECHO) 10-KT and a large free rocket (ECHO) 10-KT.

5. You determine the range from the fire capabilities overlay as follows:

— long range cannon — 24,000 meters;

— large free rocket — 16,000 meters.

6. You observe that tree blowdown along Highway 10 would constitute an obstacle to vehicular movement.

7. All necessary staff and delivery unit actions can be accomplished by 081700 hours.

Step 2. Determine DGZ and height of burst option.

1. Tentatively select target center as the DGZ. It may become necessary to displace the DGZ to avoid tree blowdown or to decrease the risk to friendly troops. Step 4 will indicate the necessary actions.

2. Select a low airburst as the height of burst option. A high airburst will decrease the effectiveness of the at-

tack. The fallout troop safety distance for an impact burst would probably encompass the friendly troops; this is normally checked during step 4.

S t e p 3. Eliminate obviously unsuitable weapons. Both delivery units are within range. A hasty estimate indicates that the minimum required R_D to provide one-third coverage is on the order of 700 meters. The table of maximum R_T and R_D shows that these systems will both provide R_D's as large as 925 meters. Neither system is eliminated at this time.

S t e p 4. Use tables to determine and apply data for:

1. Estimating damage to the target. Because the target is irregularly shaped, the visual method is used.

— long range cannon (ECHO) 10-KT.

... $R_D = 825$ meters; $d_0 = 325$ meters. Estimate how much of the target is covered by the R_D in the manner shown in Fig. 37. The estimate in this case is about one-third coverage for delayed casualties among protected personnel;

— large free rocket (ECHO) 10-KT.

...$R_D = 775$ meters; $d_0 = 435$ meters. The estimate in this case is about one-quarter coverage for delayed casualties among protected personnel. The large free rocket could tentatively be eliminated at this time. For demonstration purposes, it will be considered below.

2. Troop safety considerations:

— long range cannon (ECHO) 10-KT.

... MSD for negligible risk to unwarned, exposed personnel is 4,500 meters. This is greater than the distance to the nearest friendly troops. Troop safety is a consideration. The moderate risk distance for unwarned, exposed personnel is 3,700 meters. The negligible risk distance for warned, exposed personnel is 3,100 meters. In making his recommendations, the nuclear weapons employment officer points out that a negligible risk will be exceeded unless the troops are warned of the strike;

— large free rocket (ECHO) 10-KT.

... MSD for negligible risk to unwarned, exposed personnel is 4,300 meters. Troop safety is a consideration with this weapon. The same actions must be taken as indicated in 2 above.

3. Limiting requirements. The distance from DGZ to Highway 10 is 1,750 meters:

— long range cannon (ECHO) 10-KT. (From appropriate tables). Radius of tree blowdown, obstacles to foot and wheeled vehicle movement, type III, is 1,100 meters; d_o = 325 meters. Least separation distance for this weapon is 1,425 meters. Tree blowdown on Highway 10 is not a limitation with this weapon;

— large free rocket (ECHO) 10-KT. (From appropriate tables). Radius of tree blowdown is 1,100 meters; d_o = 435 meters. Least separation distance is 1,535 meters. Tree blowdown on Highway 10 is not a limitation with this weapon.

Step 5. Eliminate unsuitable weapon systems.

1. The large free rocket (ECHO) 10-KT is eliminated at this time because it does not give the desired coverage.

2. The long range cannon (ECHO) 10-KT is retained because it meets the requirements for attack of the target. Troop safety is a consideration as indicated above, but the weapon should not be eliminated; instead, the risk options are presented to the commander for decision.

Step 6. Evaluate weapon systems and tactical situation. Not a consideration in this case.

Step 7. Make recommendations.

1. The following recommendations are submitted by the nuclear weapons employment officer:

— weapon system — long range cannon (ECHO) 10-KT;

— height of burst option — LOW air. (The delivery unit would be given, HOB = 275 meters.);

— desired ground zero — coordinates of target centre. See 2 below;

— time of burst — 081700. See 2 below;

— estimated results — one-third coverage for delayed casualties among protected personnel.

— troop safety — moderate risk to unwarned personnel. Negligible risk to warned personnel.

2. The troop safety problem indicated above requires that alternate courses of action be presented to the commander for decision. Some of these are:

— delay attack of target so that all personnel can be warned. A negligible risk results;

— fire the weapon without warning, and accept a moderate risk;

— displace the desired ground zero. The DGZ for the long range cannon (ECHO) 10-KT must be displaced

500 meters north; the large free rocket (ECHO) 10-KT 300 meters. Displacement of the DGZ requires that a new estimate of results be made. The coverage for both weapon decreases to about one-eighth.

3. The recommendations include a graphic portrayal on a circular map scale of the following radii:

— radius of second degree burns on bare skin — 2,125 meters;

— radius of tree blowdown obstacles to foot movement — 1,100 meters;

— safety radii for fixed wing aircraft — 10,000 meters;

— radius of 2 rad/hr induced radiation contour, type III soil — 800 to 1,350 meters.

QUALITATIVE THERMAL CRITERIA FOR TROOP SAFETY CALCULATIONS

Degree of Protection (Personnel)

Type of protection	Degree of protection				
	Initial effects			Residual radiation	
Personnel	Blast	Thermal	Initial radiation	Induced	Fallout
In the open	None	None to fair. Clothing protects against heat depending on nature of material and number of layers. Air between layers of clothing provides insulation	None	None	None
Stone, brick, or concrete walls	Fair, depending on material, thickness, and type construction	Excellent against direct rays. None against rays reflected to back side of wall	Some from direct radiation. None from scattered radiation	None	None
Ditches, slit trenches	Good, depending on orientation relative to GZ	Good, depending on depth and orientation. Rays can be reflected to inside	Good, depending on depth and orientation. Radiation can be scattered to inside	None	None against entry of fallout articles. Fair against radiation from surrounding area. Decontamination of inside of ditch difficult

Continued

Type of protection	Degree of protection				
	Initial effects			Residual radiation	
Personnel	Blast	Thermal	Initial radiation	Induced	Fallout
Culverts	Good, depending on orientation relative to GZ, depth, and construction	Excellent, depending on orientation. Rays can be reflected into openings	Excellent, depending on orientation and depth. Radiation can be scattered into openings	Good, depending on depth and closing of openings with earth, sandbags, and other material	Good, providing openings are closed with earth or other material and continuous decontamination is practiced
Ravines and gullies	Fair	Excellent against direct rays. Some thermal may be scattered	Some from direct radiation. None from scattered radiation	None to fair	None to fair
Foxholes and trenches. Open	Good	Excellent against direct rays. Thermal can be reflected into foxhole	Excellent against direct radiation. None from scattered radiation	Questionable. Degree of protection depends on removing radioactive soil from surrounding area and inside foxhole or trench	Excellent, providing foxhole is covered with poncho, shelterhalf, or other material to exclude fallout and particles; decontamination is continuous after fallout is complete

Degree of Protection (Vehicles)

Type of protection	Degree of protection				
	Initial effects			Residual radiation	
Personnel	Blast	Thermal	Initial radiation	Induced	Fallout
Wheeled vehicles	None	None to fair	None	Shielding is fair. Mobility will reduce exposure time when leaving or crossing the area	Shielding is fair. Mobility will reduce exposure time when leaving or crossing the area
Armored carrier	Good	Excellent	Fair	Shielding is fair. Mobility will reduce exposure time when leaving or crossing the area	Shielding is fair. Mobility will reduce exposure time when leaving or crossing the area
Tanks	Excellent	Excellent	Excellent	Shielding is excellent. Mobility will reduce exposure time when leaving or crossing the area	Shielding is excellent. Mobility will reduce exposure time when leaving or crossing the area

Qualitative Thermal Criteria for Troop Safety Calculations

Vulnerability and risk condition	Qualitative thermal criteria
WARNED, EXPOSED: Negligible	Two-thirds of the calories required to scorch summer uniforms.
Moderate	Two-thirds of the cal/cm² required to produce first degree burns on average personnel under summer uniform.

Vulnerability and risk condition	Qualitative thermal criteria
Emergency	Two-thirds of the cal/cm² required to produce second degree burns on average personnel under summer uniform.
UNWARNED, EXPOSED: Negligible	Two-thirds of the cal/cm² required to produce first degree burns on bare skin (average personnel).
Moderate	Cal/cm² required to produce first degree burns on bare skin (average personnel).
Emergency	Two-thirds of the cal/cm² required to produce second degree burns on bare skin (average personnel).

Quantitative Effects Criteria for Troop Safety Calculations

Effects criteria	Vulnerability condition and degree of risk								
	Unwarned, exposed			Warned, exposed			Warned, protected		
	Neg	Mod	Emerg	Neg	Mod	Emerg	Neg	Mod	Emerg
Nuclear radiation rad	5	20	100	5	20	100	5	20	100
Blast-psi	. . .	. . .	. . .	. . .	. . .	. . .	3	5	10
Thermal cal/cm² 1 KT	1	2	3	3	8	13	. . .	. . .	. . .
1 MT	2	3	4	5	12	20	. . .	. . .	. . .

Note. Where no data are shown, other effects always govern.

TABLES OF CONVERSION OF METRICAL AND ENGLISH UNITS OF MEASUREMENT

CONVERSION FACTORS: LENGTH

Length	Multiply by	To Obtain
Centimeters	0.3937	Inches
	0.03281	Feet
Kilometers	3281	Feet
	0.6214	Miles
	0.5396	Nautical Miles
	1093.6	Yards
Meters	39.37	Inches
	3.281	Feet
	1.0936	Yards
Miles	5280	Feet
	0.8684	Nautical Miles
	1760	Yards
Nautical Miles	6080.2	Feet

CONVERSION FACTORS: VELOCITY

Velocity	Multiply by	To Obtain
Feet per minute	0.01136	Miles per hour
	0.01829	Kilometers per hour
	0.01667	Feet per second
Feet per second	0.6818	Miles per hour
	1.097	Kilometers per hour
	0.5921	Knots
Knots	1.0	Nautical miles per hour
	1.6889	Feet per second
	1.1515	Miles per hour
	1.8532	Kilometers per hour
Miles per hour	1.467	Feet per second
	1.609	Kilometers per hour
	0.8684	Knots

GLOSSARY

DIVISION ONE: MISSILES AND ROCKETS

A

ABLATE подвергаться абляции.

To carry away; specifically, to carry away heat generated by aerodynamic heating from a vital part, by arranging for its absorption in a non-vital part which may melt or vaporize, then fall away taking the heat with it.

ABLATING MATERIAL абляционный материал.

A material, especially a coating material, designed to provide thermal protection to a body in a fluid stream through loss of mass.

ABLATING NOSE CONE головная часть ракеты из абляционного материала.

A nose cone designed to reduce heat transfer to the internal structure by the use of an ablating material.

ABSOLUTE ALTITUDE истинная высота.

Altitude above the actual surface, either land or water, of a planet or natural satellite.

ACCELERATION ускорение.

1. The rate of change of velocity. 2. The act or process of accelerating, or the state of being accelerated. Negative acceleration is called deceleration.

ACCELEROMETER акселерометр.

A transducer which measures acceleration or gravitational forces capable of imparting acceleration.

ACCIDENTAL ERROR случайная ошибка.

In experimental observations, an error which does not always recur when an observation is repeated under the same conditions.

ACOUSTIC MACH METER акустический счетчик числа М, маметр.

A device which obtains data on sound propagation for the calculation of Mach number.

ACQUISITION обнаружение и сопровождение цели; ориентирование *(антенны)*.

1. The process of locating the orbit of a satellite or trajectory of a space probe so that tracking or telemetry data can be gathered. 2. The process of pointing an antenna or telescope so that it is pro-

perly oriented to allow gathering of tracking or telemetry data from a satellite or space probe.

ACQUISITION AND TRACKING RADAR радиолокационная установка обнаружения и сопровождения цели.

A radar set that locks onto a strong signal and tracks the object reflecting the signal.

ACTIVE активный.

Transmitting a signal, as active satellite. Antonym of **passive**.

ACTIVE HOMING активное самонаведение.

The homing of an aerodynamic or space vehicle in which energy waves (as radar) are transmitted from the vehicle to the target and reflected back to the vehicle to direct the vehicle toward the target.

ACTIVE SATELLITE активный спутник.

A satellite which transmits signals in contrast to passive satellite.

ACTIVE TRACKING SYSTEM активная система слежения.

A system which requires addition of a transponder or transmitter on board the vehicle to repeat, transmit or retransmit information to the tracking equipment.

ADAPTER переходник, соединительное устройство.

Any device or contrivance used or designed primarily to fit or adjust one thing to another, as, a joint attaching an afterburner to a turbine casing of a jet engine.

ADAPTER SKIRT расширяющийся переходник.

A control system which continuously monitors the dynamic response of the controlled system and automatically adjusts critical system parameters to satisfy preassigned response criteria, thus producing the same response over a wide range of environmental conditions.

ADDER сумматор.

In a computer a device which can form the sum of two or more numbers or quantities.

ADDRESS адрес.

Of a computer, a location where information is stored.

ADF *See* **automatic direction finder.**

AERODYNAMIC VEHICLE крылатый (аэродинамический) аппарат.

A device, such as an airplane, glider etc. capable of flights only within the sensible atmosphere and relying on aerodynamic forces to maintain flight.

AEROSPACE (*From* **aeronautics** *and* **space**) воздушно-космический.

1. Of or pertaining to both the Earth's atmosphere and space, as in aerospace industries. 2. Earth's envelope of air and space above it; the two considered as a single realm of activity in the flight of air vehicles and in the launching, guidance and control of ballistic missiles, earth satellites, dirigibles, space vehicles and the like (Aerospace in sense 2 is used primarily by the US Air Force).

AEROSPACE VEHICLE воздушно-космический летательный аппарат.

A vehicle capable of flight within and outside the sensible atmosphere.

AFC *See* **automatic frequency control.**

AFTERBODY сопровождающее тело, отделяющееся от спутника; отдельные части баллистической ракеты и космического корабля; задняя (хвостовая) часть ракеты.

1. A companion body that trails a satellite. 2. A section or piece of a rocket or spacecraft that enters the atmosphere unprotected behind the nose cone or other body that is protected for entry. 3. The afterpart of a vehicle.

AFTERBURNER камера дожигания.

A device for augmenting the thrust of a jet engine by burning additional fuel in the uncombined oxygen in the gases from the turbine.

AFTERBURNING догорание, дожигание.

1. Irregular burning of fuel left in the firing chamber of a rocket after fuel cutoff. 2. The function of an afterburner.

AFTERCOOLING охлаждение (газа) после сжатия.

The cooling of a gas after compression.

AIR BREAKUP отделение или расцепка (в атмосфере).

The breakup of a test re-entry body after re-entry into the atmosphere.

AIRBREATHER летательный аппарат с воздушно-реактивным двигателем.

An aerodynamic vehicle propelled by fuel oxidized by intake for the purpose of combustion.

AIRCRAFT летательный аппарат.

Any structure, machine, or contrivance, especially a vehicle, designed to be supported by the air, being borne up either by the dynamic action of the air upon the surfaces of the structure or object, or by its own buoyancy; such structures, machines, or vehicles collectively, as, fifty aircraft.

Aircraft in its broadest meaning, includes fixed-wing airplanes, helicopters, gliders, airships, free and captive balloons, ornithopters, flying model aircraft, kites, etc. But since the term carries a strong vehicular suggestion, it is more often applied, or recognized to apply, only to such of these craft as are designed to support or convey a burden in or through the air.

AIRCRAFT ROCKET авиационная ракета.

A rocket missile designed to be carried by, and launched from, an aircraft.

AIRFOIL аэродинамическая поверхность.

A structure piece, or body, originally likened to a foil or leaf in being wide and thin designed to obtain a useful reaction on itself and its motion through the air.

AIRFRAME корпус (ракеты), планер (самолета).

The assembled structural and aerodynamic components of an aircraft or rocket vehicle that support the different systems and subsystems integral to the vehicle.

The word airframe, a carry-over from aviation usage, remains appropriate for rocket vehicles since a major function of the airframe is performed during flight within atmosphere. There is a disagreement as to whether the nose cone and combustion chambers are included in the term airframe while they are attached to the vehicle.

AIR LAUNCH запуск в воздухе.

To launch from an aircraft in the air, as to airlaunch a guided missile.

AIRSPACE воздушное пространство.

Specifically, the atmosphere above a particular portion of the Earth, usually defined by boundaries of an area on the surface projected upward.

AIR-SPACE воздушно-космический.

Of or pertaining to both the atmosphere and space. (Because this adjective is pronounced as the noun airspace is, it is subject to misunderstanding. Aerospace is commonly used instead).

ALGA (*plural*, algae) морская водоросль.

Any plants of a group of unicellular primitive organisms that include the chlorella, scenedesmus and other genera. (In a closed ecological system a source of food).

ALGORITHM алгоритм.

A special mathematical procedure for solving particular type of problem.

ALL BURNT полное выгорание топлива *(момент)*.

The time at which a rocket consumes its propellants.

ALL-INERTIAL GUIDANCE чисто инерциальное управление.

The guidance of a rocket vehicle entirely by use of inertial devices; the equipment used for this.

ALTITUDE высота.

Height, especially radial distance as measured above a given datum, as average sea level. In space navigation altitude designates dimension from the mean surface of the reference body as contrasted to distance which designates dimension from the center of the reference body.

AMBIENT (*symbol* a *used as a subscript*) окружающий, внешний.

Surrounding, especially, of or pertaining to the environment about a flying aircraft or other body, undisturbed or unaffected by it as in **ambient air** or **ambient temperature**.

AMPLIFIER усилитель.

A device which enables an imput signal to control a source of power, and thus is capable of delivering at its output an enlarged reproduction of the essential characteristics of the signal.

ANALOG COMPUTER аналоговая счетная машина.

A computing machine working on a principle of measuring as distinguished from counting in which the imput data is analogous to a measurement continuum, such as linear lengths, voltages, resistances which can be manipulated by the computer.

AND операция „и“ (конъюнкции) в Булевой алгебре.

In Boolean algebra, the operation of intersection.

AND GATE контур „и“ (конъюнкции).

A circuit or device used in computers whose output is energized only when every input is in its prescribed state. It performs the logical function of the **and**, the Boolean operation of intersection.

ANGLE OF ATTACK угол атаки.

The angle between a reference line fixed with respect to an airframe and a line in the direction of movement of the body.

ANGLE OF CLIMB угол подъема.

The angle between the flight path of a climbing vehicle and the local horizontal.

ANGLE OF ELEVATION угол возвышения.

The angle in a vertical plane between the local horizontal and an ascending line as an observer to an object. A negative elevation angle is usually called the angle of depression.

ANGLE OF PITCH угол тангажа.

The angle as seen from the side, between, the longitudinal body axis of an aircraft or similar body and a chosen reference line or plane, usually the horizontal plane.

ANGLE OF ROLL угол крена.

The angle that the lateral body axis of an aircraft or similar body makes with a chosen reference plane in rolling; usually the angle between the lateral axis and a horizontal plane. The angle of roll is considered positive if the roll is to starboard.

ANGLE OF YAW угол рыскания.

The angle as seen from above, between the longitudinal body axis of an aircraft, rocket, or the like and a chosen reference direction. The angle is positive when the forward part of the longitudinal axis is directed to starboard. Also called **yaw angle.**

APHELION афелий.

That point in a solar orbit which is most distant from the Sun. The point nearest the Sun is called perihelion.

APOGEE апогей; достигать апогея.

1. That point in a geocentric orbit which is most distant from the Earth. That orbital point nearest the Earth is called perigee. (By extension, apogee and perigee are also used in reference to orbits about other planets and natural satellites). 2. Of a satellite or rocket: To reach its apogee (sense 1) as in **the Vanguard apogees at 2560 miles.**

APRON фартук *(заправочной горловины ракеты).*

Specifically, a protective device specially designed to cover an area surrounding the fuel inlet on a rocket or spacecraft.

ARTIFICIAL ASTEROID искусственный спутник Солнца, искусственный астероид.

A manmade object placed in orbit about the Sun.

ARTIFICIAL EARTH SATELLITE искусственный спутник Земли.

A manmade earth satellite, as distinguished from the Moon.

ASCENDENT подъем.

The negative of the gradient.

ASSISTED TAKE-OFF взлет с ускорителем.

A take-off of an aircraft using a supplementary source of power, usually a rocket.

ASTRONAUT космонавт.

A person who rides in a space vehicle.

ASTRONAUTICS астронавтика, космонавтика.

1. The art, skill, or activity of operating spacecraft. 2. In a broader sense the science of space flight.

ATOMIC ROCKET ракета с атомным двигателем.

A rocket engine in which the energy for the jetstream is to be generated by atomic fission or fusion.

ATTITUDE положение в пространстве.

The position or orientation of an aircraft, spacecraft etc. either in motion or at rest, as determined by the relationship between its axes and some reference line or plane or some fixed system of reference axes.

ATTITUDE CONTROL управление положением в пространстве; система управления положением в пространстве.

1. The regulation of the attitude of an aircraft, spacecraft etc. 2. A device or system that automatically regulates and corrects altitude, especially of a pilotless vehicle.

ATTITUDE JET струйные рули управления, стабилизации и ориентации.

A jetstream used to correct or alter the attitude of a flying body either in the atmosphere or in space; the nozzle that directs this stream. The jet may be continuous or intermittent. A vernier engine is sometimes used to produce it.

AUTOMATIC COMPUTER автоматическое счетно-решающее устройство.

A computer which can automatically perform a comprehensive sequence of operations.

AUTOMATIC CONTROL автоматическое управление.

Control of devices and equipment, including aerospace vehicles, by automatic means.

AUTOMATIC DATA PROCESSING SYSTEM автоматическая система обработки данных.

An electronic system that includes an electronic data processing system plus auxiliary and connecting communication equipment.

AUTOMATIC DIRECTION FINDER автопеленгатор.

A radio direction finder which automatically and continuously provides a measure of the direction of arrival of the received signal. Data are usually displayed visually.

AUTOMATIC FREQUENCY CONTROL автоматический регулятор частоты.

An arrangement whereby the frequency of an oscillator is automatically maintained within specified limits.

AUTOMATIC PILOT автопилот.

Equipment which automatically stabilizes the attitude of a vehicle about its pitch, roll and yaw axes. Also called **autopilot.**

B

BALLISTIC BODY тело, падающее по баллистической кривой.

A body free to move, behave, and be modified in appearance, contour or texture by ambient conditions, substances, or forces, as by the pressure of gases in a gun by rifling in a barrel, by gravity, by temperature or by air particles. A rocket with its self-contained propulsion unit is not considered a ballistic body during the period of its guidance or propulsion.

BALLISTIC MISSILE баллистическая управляемая ракета.

A missile designed to operate primarily in accordance with the laws of ballistics. (A ballistic missile is guided during a portion of its flight, usually the upward portion and is under no thrust from its propelling system during the latter portion of its flight; it describes a trajectory similar to that of an artillery shell).

BALLISTICS баллистика.

The science that deals with the motion, behaviour and effects of projectiles, especially bullets, aerial bombs, rockets or the like.

BALLISTIC TRAJECTORY баллистическая траектория.

The trajectory followed by a body being acted upon only by gravitational forces and the resistance of the medium through which it passes. (A rocket without lifting surfaces is in a ballistic trajectory after its engines cease operating).

BALLISTIC VEHICLE баллистический летательный аппарат.

A nonlifting vehicle; a vehicle that follows a ballistic trajectory.

BALLOON-TYPE ROCKET ракета с наддувом баков.

A liquid-fuel rocket, that requires the pressure of its propellants (or other gases) within it to give it structural integrity.

BEAM RIDER летательный аппарат, наводимый по лучу.

A craft following a beam, particularly one which does so automatically, the beam providing the guidance.

BEAM-RIDER GUIDANCE система наведения по лучу.

A system for guiding aircraft or spacecraft in which a craft follows a radar beam, light beam, or other kind of beam along the desired path. Also called **beam-climber guidance.**

BEARING азимут; курс.

The horizontal direction of an object or point, usually measured clockwise from a reference line or direction through 360°.

BEARING ANGLE угол; азимут.

Horizontal direction measured from 0° at the reference direction clockwise or counter-clockwise through 90° or 180°.

BEAT такт.

One complete cycle of variations in the amplitude of two or more periodic phenomena of different frequency which mutually react.

BINARY DIGIT однозначное число, записанное в двоичной системе.

A digit (0 or 1) in binary notation.

BINARY NOTATION двоичная система записи.

A system of positional notation in which the digits are coefficients of powers of the base 2 in the same way as the digits in the conventional system are coefficients of powers of the base 10.

BIOSATELLITE биологический спутник.

An artificial satellite which is specifically designed to contain and support man, animals, or other living material in a reasonably normal manner for an adequate period of time and which particularly for man and animals, possesses the proper means for safe return to the earth.

BIPROPELLANT ROCKET ракета с двухкомпонентным ракетным двигателем.

A rocket using two separate propellants which are kept separate until mixing in the combustion chamber.

BIT бит; двоичная единица информации.

1. An abbreviation of binary digit. 2. A quantum of information.

BLACK BOX черный ящик.

An engineering design, a unit whose output is a specified function of the input, but for which the method of converting input to output is not necessarily specified.

BLANKET заглушать прием.
To black out or obscure weak radio signals by a stronger signal.
BLAST CHAMBER камера сгорания.
A combustion chamber, especially a combustion chamber in a gas-turbine engine, jet engine, or rocket engine.
BLAST DEFLECTOR пламеотражатель.
A device used to divert the exhaust of a rocket fired from a vertical position.
BLASTOFF пуск ракеты.
A missile launch (*slang*).
BLIP отметка, импульс, выброс.
A spot of light or deflection of the trace on a radarscope, loran indicator or the like, caused by the received signal, as from a reflecting object. Also called **a pip** or **an echo**.
BLOWOFF выбрасывание (приборного контейнера из ракеты).
The action of applying an explosive force and separating a package section away from the remaining part of a rocket vehicle or re-entry body, usually to retrieve an instrument or to obtain a record made during early flight.
BLUFF BODY плохо обтекаемое тело.
A body having a broad, flattened front, as in some re-entry vehicles.
BODY тело, корпус, основная часть, фюзеляж.
The main part or main central portion of an airplane, airship, rocket or the like; a fuselage or a hull.
BOILERPLATE MODEL металлический макет летательного аппарата.
A metal copy of a flight vehicle, the structure or components of which are heavier than the flight model.
BOILOFF утечка паров летучей жидкости.
The vaporization of a liquid, such as liquid oxygen or liquid hydrogen as its temperature reaches its boiling point under conditions of exposure as in the tank of a rocket being readied for launch.
BOOST ускорение, разгон; наддув; выводить на орбиту (с помощью ракеты-носителя).
1. Additional power, pressure, or force supplied by a booster, as hydraulic boost, or extra propulsion given a flying vehicle during lit-off climb, or other part of its flight as with booster engine. 2. To launch or to push along during a portion of flight, as **to boost a ramjet to flight speed by means of a rocket or a rocket boosted to altitude with another rocket.**
BOOSTER ускоритель; стартовый двигатель; ракета-носитель.
1. Short for booster engine or booster rocket. 2. A rocket motor, either solid or liquid, that assists the normal propulsive system or sustainer engine of a rocket or aeronautical vehicle in some phase of its flight. 3. A rocket used to set a vehicle in motion before another engine takes over. (In sense 3 the term launch vehicle is preferred).
BRAKING ROCKET *See* **retrorocket.**
BURNER *See* **combustion chamber.**
BURNING RATE (symbol **r**) скорость горения.
The velocity at which a solid propellant in a rocket is consumed. (Usually expressed in inches per a second).

BURNING RATE CONSTANT (symbol a) константа скорости горения.

A constant related to initial grain temperature, used in calculating the burning rate of a rocket propellant grain.

BURNOUT прекращение горения; прогар.

1. An act or instance of fuel or oxidant depletion or, ideally, the simultaneous depletion of both; the time at which this occurs. Compare: **cutoff**. (In the United Kingdom **all burnt** is preferred to **burnout**). 2. An act or instance of something burning out or of overheating; specifically, an act or instance of a rocket combustion chamber, nozzle or other part overheating so as to result in damage or destruction.

BURNOUT VELOCITY скорость в момент выгорания топлива.

The velocity of a rocket, rocket powered aircraft, or the like at the time the fuel or oxidant or both are depleted. Also called **burnt velocity.**

C

CARD перфокарта.

A punched card used in a computer operations for the storage of information in the forms of holes punched through the card material.

CARRIER ROCKET ракета-носитель.

A rocket vehicle used to carry something as in **the carrier rocket of the first artificial earth satellite.**

CELESTIAL-INERTIAL GUIDANCE астроинерциальное управление (наведение).

The process of directing the movements of an aircraft or spacecraft, especially in the selection of a flight path, by inertial guidance system which also receives inputs from observations of celestial bodies.

CHAMBER *See* **combustion chamber.**

CHAMBER PRESSURE давление в камере сгорания.

The pressure of the rocket combustion chamber including the convergent portion of the nozzle up to the throat.

CHAMBER VOLUME объем камеры сгорания.

The volume of the rocket combustion chamber including the convergent portion of the nozzle up to the throat.

CHUGGING неустойчивое горение с низкочастотными колебаниями.

A form of combustion instability in a rocket engine, characterized by a pulsing operation at a fairly low frequency. Also called **chuffing, bumping.**

CIRCULAR ERROR PROBABLE *See* **circle of equal probability.**

CLEANUP очистка, промывка (ЖРД после выключения).

In aeronautics, the process of improving external shape and smoothness of an aircraft to reduce its drag.

CLUSTER связка, пакет (ракетных двигателей).

Two or more rocket motors bound together so as to function as one propulsion unit.

CODE код.

A system of symbols or signals for representing information and the rules for associating them.

COMBUSTION CHAMBER камера сгорания.

Any chamber for the combustion of fuel, specifically that part of the rocket engine in which the combustion of propellant takes place at high pressure. Also called **chamber, firing chamber**.

COMMAND команда, командный импульс.

A signal which initiates or triggers an action in the device which receives the signal. In computer operations also called **instruction**.

COMMAND CONTROL командная система управления.

A system whereby functions are performed as the result of transmitted signal.

COMMAND DESTRUCT механизм подрыва ракеты по команде.

A command control system that destroys a flightborne test rocket, actuated on command of the range safety officer whenever the rocket performance indicates a safety hazard.

COMMAND GUIDANCE командное наведение.

The guidance of spacecraft or a rocket by means of electronic signals sent to receiving devices in the vehicle.

COMMUNICATIONS SATELLITE спутник связи.

A satellite designed to reflect or relay electro-magnetic signals used for communication.

COMPARATOR сравнивающее устройство, компаратор.

In computer operations a device or circuit for comparing information from two sources.

COMPLEX. *See* **launch complex.**

COMPOSITE PROPELLANT смесевое ракетное топливо.

A solid rocket propellant consisting of a fuel and an oxidizer neither of which would burn without presence of the other.

COMPUTER счетно-решающее устройство.

A machine for carrying out calculations and performing specified transformations on information. Also called **computing machine**.

CONSOLE пульт управления.

An array of controls and indicators for the monitoring and control of a particular sequence of actions, as in the checkout of a rocket, a countdown action, or a launch procedure. (A console is usually designed around desklike arrays. It permits the operator to monitor and control different activating instruments, data recording instruments or event sequencers).

CONTROL управление; управляющее устройство; управлять.

(*In plural*) 1. A system or assembly of levers, gears, wheels, cables, boosters, valves, etc. used to control the attitude, direction, movement, power and speed on an aircraft, rocket, spacecraft, etc. 2. Control surfaces or devices. 3. Specifically, to direct the movements of an aircraft or rocket with particular references to changes in attitude and speed. Compare **guidance**.

CONTROL ROCKET управляющий ракетный двигатель.

A vernier engine, retrorocket or other such rocket, used to change the attitude of, guide or make small changes in the speed of a rocket, spacecraft, or the like.

COOLANT охлаждающая жидкость.

A liquid or gas used to cool something, as a rocket combustion chamber.

COSMIC космический.

Of or pertaining to the universe, especially that part of it outside the Earth's atmosphere.

COUNTDOWN временная развертка; предстартовый отсчет времени.

1. A step-by-step process that culminates in a climatic event, each step being performed in accordance with a schedule marked by a count in inverse numerical order; specifically this process is used in leading up to the launch of a large or complicated rocket vehicle, or in leading up to a captive test, a readiness firing, a mock firing, or other firing test. 2. The act of counting inversely during this process. (In sense 2 the countdown ends with T-time. Thus "T" minus 60 minutes to go, excepting for holds and recycling. The countdown may be hours, minutes or seconds. At the end it narrows down to seconds, 4—3—2—1—0.)

CRYOGENICS криогеника.

The study of the methods of producing very low temperatures.

CUTOFF or **CUT-OFF** отключение, выключение, отсечка.

An act or instance of shutting off; specifically in rocketry, an act or instance of shutting off the propellant and flow in a rocket, or of stopping the combustion of the propellant.

CYBERNETICS кибернетика.

The study of methods of control and communication which are common to living organisms and machines.

D

DATA ACQUISITION STATION станция приема данных и передачи управляющих команд.

A ground station at which various functions to control satellite operations and to obtain data from the satellite are performed.

DATA LINK линия передачи данных.

Any communication channel or circuit used to transmit data from a sensor to a computer, a readout device, or a storage device.

DEBUG отыскивать неисправности; доводить.

In electronic manufacturing, to operate equipment under specified environmental and test conditions in order to eliminate early failures and to stabilize equipment prior to actual use. Also called **burn-in.**

DOCKING стыковка, соединение.

The act of coupling two or more orbiting objects; the operation of mechanically connecting together or in some manner bringing together orbital payloads.

DOUBLE-BASE PROPELLANT двухкомпонентное твердое топливо.

A solid rocket propellant using two unstable compounds such as nitrocellulose and nitroglycerine. (The unstable compounds used in a double base propellant do not require a separate oxidizer).

DRAG лобовое сопротивление; торможение.

A retarding force acting upon a body in motion through a fluid, parallel to the direction of motion in the body. It is a component of the total fluid forces acting on the body.

DRIFT снос.

The lateral divergence from the prescribed flight path of an aircraft or a rocket due primarily to the effect of a cross-wind.

DUAL THRUST двухступенчатая тяга.

A rocket thrust derived from two propellant grains using the same propulsion section of a missile. The dual-thrust technique is considered to provide what is in effect a two-stage propulsion system without the disadvantages of jettisoning the booster unit and with the advantages of lower weight and shorter length.

DUCT сопло; трубопровод.

Specifically a tube or passage that confines and conducts a fluid as a passage for the flow of air to the compressor of a gas turbine engine; a pipe leading air to supercharger etc.

E

EARTH SATELLITE спутник Земли.

A body that orbits about the Earth; specifically, an artificial satellite placed in orbit by man.

EDDY вихревое движение.

In a fluid, any circulation drawing its energy from a flow of much larger scale and brought about by pressure irregularities.

EDUCATION обучение.

Of a computer, stores subroutines and subprograms which are available for the use in automatic programming.

EJECTION CAPSULE катапультируемая кабина (капсула).

1. In an aircraft or manned spacecraft, a detachable compartment serving as a cockpit or a cabin which may be ejected as a unit and parachuted to the ground. 2. A satellite, probe or unmanned spacecraft, a boxlike unit, usually containing recording instruments or records of observed data which may be ejected and returned to earth by a parachute or other deceleration device.

ELECTRICAL ENGINE электрический двигатель.

A rocket engine in which the propellant is accelerated by some electrical device. Also called **electric propulsion system, electric rocket.**

ELECTRIC PROPULSION электрический движитель.

A general term encompassing all the various types of propulsion in which the propellant consists of charged electrical or magnetic fields, or both; for example, electrostatic propulsion, electromagnetic propulsion, electrothermal propulsion.

ELECTROMAGNETIC ROCKET *See* **plasma rocket.**

ESCAPE ROCKET ракетный двигатель системы отбрасывания.

A small rocket engine attached to the leading edge of the escape tower which may be used to provide additional thrust to the capsule to obtain separation from the booster vehicle in an emergency.

ESCAPE VELOCITY скорость убегания; вторая космическая скорость.

The radial speed which a particle or larger body must attain in order to escape from gravitational field of a planet or a star.

EXHAUST STREAM струя выхлопных газов.

The stream of gaseous, atomic or radiant particles that emit from the nozzle of a rocket or other reaction engine.

FAIL SAFE SYSTEM система обеспечения надежности.
A system used to minimize risk in case of malfunction.

FALLAWAY SECTION отделяемая секция.
A section of a rocket vehicle that is cast off and separates from the vehicle during flight, especially such a section that falls back to earth.

FEED вводить (сигнал); ввод (сигнала); входной сигнал.
1. To provide a signal. 2. The point at which a signal enters a circuit or a device, as **antenna feed**. 3. The signal entering a circuit or a device; input.

FEEDBACK обратная связь.
The return of a portion of the output of a device to the input. Positive feedback adds to the input, negative feedback subtracts from the input.

FENCE заградительная линия (радиолокационных станций обнаружения).
1. A line of readout or tracking stations for pickup of signals from an orbiting satellite. 2. A line or network of radar or radio stations for detection of satellite in orbit.

FIN стабилизатор; охлаждающее ребро.
1. A fixed adjustable airfoil or vane attached longitudinally to an aircraft rocket or similar body to provide stabilizing effect. 2. A projecting flat plate or structure as a **cooling fin**.

FIRING запуск; пуск.
1. The action or event of igniting a rocket engine. 2. The action or event of launching a rocket.

FIRING CHAMBER *See* **combustion chamber.**

FIXED-AREA EXHAUST NOZZLE сопло с нерегулируемым выходным сечением.
On a jet engine, an exhaust nozzle exit opening which remains constant in area. Compare **variable-area exhaust nozzle.**

FIXED SATELLITE стационарный („неподвижный“) искусственный спутник Земли.
A satellite that orbits the Earth from west to east at such a speed as to remain fixed over a given place on the earth's equator at approximately 35,900 kilometers altitude.

FLAME BUCKET ковшеобразный пламеотражатель.
A deep cavelike construction built beneath a launcher, open at the top to receive the hot gases of the rocket positioned above it, and open on one or three sides below with a thick metal fourth side bent toward the open sides as to deflect the exhausting gases.

FLAME DEFLECTOR пламеотражатель.
In a vertical launch, any of variously designed obstructions that intercept the hot gases of the rocket engine so as to deflect them away from the ground or from a structure.

FLASHBACK обратная вспышка.
A reversal of flame in a system counter to the usual flow of combustible mixture.

FLICKER CONTROL отклонение радиосигнала управления по принципу „да — нет“.
Control of an aircraft, rocket, etc. in which the control surfaces

are deflected to their fullest degree with any motion of the remote control. Compare **proportional control.**

FLIGHT ATTITUDE пространственное положение (в полете).

The attitude of an aircraft, rocket, etc. in flight; specifically, the attitude of an aircraft with respect to the relative wind.

FLIGHT PATH траектория полета.

The path made or followed in the air or in space by an aircraft, rocket etc.; the continuous series of positions occupied by a flying body, more strictly, the path of the center of gravity of the flying body, referred to the earth or other fixed reference.

FLIGHT SIMULATOR тренажер, моделирующий условия полета.

A training device or apparatus that simulates certain conditions of actual flight or flight operations.

FLIGHT SPACE пространство для полетов.

The space above and beyond the Earth's surface now used, or potentially to be used, for flight of aircraft, spacecraft or rockets.

FLIP-FLOP триггерное устройство.

A device having two stable states and two input terminals (or types of input signals) each of which corresponds with one of two states. The circuit remains in either state until caused to change to the other state by application of corresponding signal.

FLYBY пролет (мимо планеты).

An interplanetary mission in which the vehicle passes close to the target planet but does not impact it or go into orbit around it.

FREE FALL свободное падение.

The fall or drop of a body such as a rocket, not guided, not under thrust and not retarded by a parachute or other braking device.

G

"g" *or* **"G"** ускорение силы тяжести.

An acceleration equal to the acceleration of gravity approximately 32.2 feet per second per second at sea level. Used as a unit of stress measurement for bodies undergoing acceleration.

GANTRY портальный кран.

A frame structure that spans over something, as an elevated platform that runs astride the work area, supported by wheels on each side. Short for **gantry crane or gantry scaffold.**

GARBAGE находящиеся на орбите объекты, сопутствующие ракете.

Miscellaneous objects in orbit, usually material ejected or broken away from a launch vehicle or satellite.

GAS-TURBINE ENGINE газотурбинный двигатель.

An engine incorporating as its chief element a turbine rotated by expanding gases. In its most usual form it consists essentially of a rotary air compressor with an air intake one or more combustion chambers, a turbine and an exhaust outlet.

GLIDE планирование.

A controlled descent by a heavier-than-air aeronautical vehicle under little or no engine thrust in which forward motion is maintained by gravity and vertical descent is controlled by lift force.

GLIDER планер *(летательный аппарат без силовой установки)*.
A fixed wing aircraft specially designed to glide or to glide and soar. This kind of aircraft usually has no powerplant.

GRAIN шашка твердого топлива.
An elongated molding or extrusion of solid propellant for a rocket, regardless of size.

GROSS THRUST полная (максимальная) тяга.
The total thrust of a jet engine without deduction of the drag due to the momentum of the incoming air (ram drag). The gross thrust is equal to the product of the mass rate of fluid flow and the velocity of the fluid relative to the nozzle, plus the product of the nozzle exit area and the difference between the exhaust pressure and ambient pressure.

GROSS WEIGHT стартовый вес.
The total weight of an aircraft, rocket, etc. as loaded; specifically, the total weight with full crew, full tanks, payload etc. Also called **take-off weight.**

GROUND SUPPORT EQUIPMENT наземное вспомогательное оборудование.

That equipment on the ground, including all implements, tools and devices (mobile or fixed), required to inspect, test, adjust, calibrate, appraise, gage, measure, repair, overhaul, assemble, disassemble, transport, safeguard, record, store or otherwise function in support of a rocket, space vehicle, or the like, either in the research and development phase or in an operational phase, or in support of the guidance system used with missile, vehicle or the like. (The ground support equipment is not considered to include land or building; nor does it include the guidance station equipment itself, but it does include the test and checkout equipment required for operation of the guidance station equipment).

GSE *See* **ground support equipment.**

GUIDANCE наведение, управление.
The process of directing the movement of an aeronautical vehicle or space vehicle, with particular reference to the selection of flight path.

In preset guidance a predetermined path is set up into the guidance mechanism and not altered, in inertial guidance accelerations are measured and integrated within the craft, in command guidance the craft responds to information received from an outside source. Beam-rider guidance utilizes a beam; terrestrial-reference guidance, some influence of the earth; celestial guidance, the celestial bodies and particularly the stars; and homing guidance, information from the destination. In active homing guidance the information is in response to transmission from the craft, in semiactive homing guidance, the transmissions are from a source other than the craft and in passive homing guidance natural radiations from the destination are utilized. Midcourse guidance extends from the end of the launching phase to an arbitrary point enroute and terminal guidance extends from this point to the destination.

GUIDED MISSILE управляемая ракета, управляемая авиационная ракета.
1. Broadly, any missile that is subject to or capable of some degree of guidance or direction after having been launched, fired, or

otherwise set in motion. 2. Specifically, an unmanned, self-propelled flying vehicle (such as pilotless aircraft or rocket) carrying a destructive load and capable of being directed or of directing itself after launching or take-off, responding either to external direction or to direction originating from devices within missile itself. 3. Loosely, by extension any steerable projectile (e. g. ballistic missile).

H

HEAT SHIELD тепловой (защитный) экран.

1. Any device that protects something from heat. 2. Specifically, the protective structure necessary to protect a re-entry body from aerodynamic heating.

HOLD задержка при предпусковой подготовке; память (кибернетического устройства).

1. During countdown to stop counting and to wait until an impediment has been removed so that the countdown can be resumed as in **"T" minus 40 and holding**. Compare **count, recycle**. 2. In computer terminology, to retain information in one storage device after copying it into another storage device.

HYPERSONIC гиперзвуковой.

Pertaining to speed of Mach 5 or greater.

HYPERSONIC FLOW гиперзвуковой поток.

In aerodynamics, flow of a fluid over a body at speeds much greater than the speed of sound and in which the shock waves start at a finite distance from the surface of the body.

HYPERSONIC GLIDER гиперзвуковой планирующий летательный аппарат.

An unpowered vehicle, specifically a re-entry vehicle, designed to fly at hypersonic speed.

I

IMPACT попадание, встреча с целью.

1. Specifically, the action or event of an object, such as rocket striking the surface of a planet or natural satellite (or target in case of missile). 2. Of a rocket or fallaway section: To collide with a surface (target) as in **rocket impacted 10 minutes after launch**.

INHIBITOR бронировка твердого топлива (ингибитор).

Specifically, a substance bonded, taped, or dip dried onto a solid propellant to restrict the burning surface and to give direction to the burning process.

INITIAL MASS стартовая масса.

The mass of a rocket vehicle at launch.

INJECTION впрыскивание; вывод на орбиту.

1. The introduction of fuel, fuel and air, fuel and oxidizer, water, or other substance into an engine induction system or combustion chamber. 2. The process of putting an artificial satellite into orbit. 3. The time following launching when nongravitational forces (thrust, lift, and drag) become negligible in their effect on the trajectory of a rocket or spacecraft).

INPUT ввод.

The path through which information is applied to any device.

INSERTION выведение на орбиту.

The process of putting an artificial satellite or spacecraft into orbit.

INSTRUCTION инструкция, команда.

1. Information which tells a computer to obtain the operands, what operation to perform, what to do with the result and sometimes where to obtain the next instruction. 2. Command.

J

JET реактивная струя; сопло; реактивный двигатель.

1. A strong well-defined stream of fluid either issuing from an orifice or moving in a contracted duct, such as the jet of combustion gases issuing from a reaction engine, or the jet in the test section of a wind tunnel. 2. A tube, nozzle, or the like through which fluid passes or from which it issues in a jet, such as a jet in a carburetor. 3. A jet engine as an airplane with jets slung in pods.

JETAVATOR (кольцевой) газовый руль, отклоняемый (кольцевой) насадок сопла.

A control surface that may be moved into or against a rocket jetstream, used to change the direction of the jet flow for thrust vector control.

JET ENGINE реактивный двигатель.

Broadly, any engine that ejects a jet or stream of gas or fluid, obtaining all or most of its thrust by reaction to the ejection.

JET NOZZLE реактивное сопло.

A nozzle, usually specially shaped for producing a jet such as the exhaust nozzle on a jet or rocket engine.

JET THRUST тяга реактивного двигателя.

The thrust of fluid, especially as distinguished from the thrust of a propeller.

JET VANE газовый руль.

A vane, either fixed or movable, used in a jetstream, especially in a jetstream of a rocket, for purposes of stability or control under conditions where external aerodynamic control is ineffective.

L

LAG задержка, запаздывание.

1. The delay between change of conditions and the indication of the change on an instrument. 2. Delay in human reaction. 3. The amount one cyclic motion is behind another, expressed in degrees. The opposite is lead.

LASER лазер.

(*From* **light amplification by stimulated emission of radiation**) A device for producing light by emission of energy stored in a molecular or atomic system when stimulated by an input signal.

LAUNCH пуск, старт; запуск; время запуска.

1. The action taken in launching a rocket from the surface. 2. The resultant of the action i. e., the transition from static repose to dynamic flight by the rocket. 3. The time at which it takes place. 4. The action of sending forth a rocket, probe, or other object from a moving vehicle such as an aircraft or a spacecraft.

LAUNCH запускать, катапультировать.

1. To send off a rocket vehicle under its own rocket power as in the case of guided aircraft rockets, artillery rockets and space vehicles. 2. To send off a missile or an aircraft by means of a catapult or by means of inertial force. 3. To give a space probe an added boost for flight into space just before separation from its launch vehicle.

LAUNCH COMPLEX стартовый (пусковой) комплекс.

The site, facilities, and equipment used to launch a rocket vehicle. (The complex differs according to the type of rocket or particular rocket or according to whether landlaunched or shiplaunched. The term is sometimes considered to include the launch crew.

LAUNCH CREW расчет пусковой установки.

A group of technicians that prepares and launches a rocket.

LAUNCH EMPLACEMENT стартовая площадка.

A launch pad with associated equipment.

LAUNCHER пусковая установка; стартовое сооружение.

1. Specifically, a structure or device often incorporating a tube, a group of tubes, or a set of tracks from which self-propelled missiles are sent forth and by means of which the missiles usually are aimed or imparted initial guidance — distinguished in this specific sense from a catapult. 2. Broadly, a structure, machine or device, including the catapult, by means of which airplanes, rockets or the like are directed, hurled, or sent forth.

LAUNCHING RACK пусковая рама.

A skeletonelike structure usually incorporating rails, from which something is launched.

LAUNCHING RAIL рельсовая направляющая (пусковой установки).

A rail that gives initial support and guidance to a rocket launched in a nonvertical position.

LAUNCH PAD стартовая площадка.

The load-bearing base or platform from which a rocket vehicle is launched. Usually called **pad**.

LAUNCH SITE стартовая позиция; ракетная база.

1. A defined area from which a rocket vehicle is launched either operationally or for test purposes. 2. More broadly a launching base. (Also called **launching site**).

LAUNCH STAND пусковая установка.

A facility or station at which a rocket vehicle is launched, normally incorporating a launch pad with launcher.

LAUNCH VEHICLE ракета-носитель.

A rocket or other vehicle used to launch a probe, satellite, or the like.

LIQUID FUEL жидкое ракетное горючее.

A rocket fuel which is liquid under the conditions in which it is utilized in the rocket.

LIQUID PROPELLANT жидкое ракетное топливо.

Specifically, a rocket propellant in liquid form. Examples of liquid propellants include fuels such as alcohol, gasoline, aniline, liquid ammonia, and liquid hydrogen, oxidants, such as liquid oxygen, hydrogen peroxide (also applicable as a monopropellant) and nitric acid; additives such as water; and monopropellants such as nitromethane.

LIQUID-PROPELLANT ROCKET ракета с жидкостным ракетным двигателем.

1. A rocket powered by a liquid propellant rocket engine. 2. *See* **liquid propellant rocket engine.**

LIQUID-PROPELLANT ROCKET ENGINE жидкостный ракетный двигатель (ЖРД).

A rocket engine using a propellant in liquid form. Also called **liquid propellant rocket.**

LOX жидкий кислород; заправлять (ракету) жидким кислородом.

1. Liquid oxygen. Used attributively as in **lox tank, lox unit.** Also called **loxygen.** 2. To load the fuel tanks of a rocket vehicle with liquid oxygen. Hence **loxing.**

LOZ жидкий озон.

Liquid ozone.

LP *See* **liquid propellant.**

LUNAR PROBE ракета для изучения Луны.

A probe for exploring and reporting on conditions on or about the moon.

LUNAR SATELLITE искусственный спутник Луны.

A manmade satellite that would make one or more revolutions about the moon.

M

MACH *See* **Mach number.**

MACH NUMBER число М.

(*Pronounced* **mock**). A number expressing the ratio of the speed of a body or of a point on a body with respect to the surrounding air or other fluid, or the speed of a flow, to the speed of sound in the medium. If the Mach number is less than 1, the flow is called **subsonic.** If Mach number is greater than 1 the flow is called **supersonic.**

MARRIAGE *See* **mating.**

MASER мазер.

An amplifier utilizing the principle of microwave amplification by stimulated emission of radiation.

MATE соединять, пригонять.

To fit together two major components of a system. Also called **marry.**

MATING стыковка.

1. The act of fitting together two major components of a system as **mating of a launch vehicle and a spacecraft.** Also called **marriage.**

MISSILE снаряд; реактивный снаряд; ракета; управляемый реактивный снаряд.

Any object thrown, dropped, fire launched or otherwise projected with the purpose of striking a target; short for **guided missile. Missile** should not be used loosely as a synonym for **rocket** or **spacecraft.**

MISSILERY ракетная техника; ракетостроение.

The art or science of designing developing, building, launching directing and sometimes guiding a rocket missile; any phase or aspect of this art or science. (The term is sometimes spelled **missilry** and pronounced as a threesyllable word).

MOCK TEST стендовое (холодное) испытание ракетной системы.

An operational test of a complete rocket system without actually firing a rocket.

MOCKUP макет; модель в натуральную величину.

A full sized replica or dummy of something, such as spacecraft, often made of some substitute material such as wood and sometimes incorporating actual functioning pieces of equipment, such as engines.

MODULE отсек (кабина); модульный блок.

1. A self-contained unit of a launch vehicle or spacecraft which serves as a building block for overall structure. The module is usually designated by its primary function as **command module, lunar landing module, etc.** 2. A one-package assembly of functionally associated electronic parts, usually a plug-in unit so arranged as to function as a system, a subsystem or a black box.

MONITOR проверять, контролировать, наблюдать.

To observe, listen in on, keep track of, or exercise surveillance over by any appropriate means as **to monitor radio signals, to monitor the flight of a rocket by radar, to monitor a landing approach.**

MONOCOQUE монокок.

A type of construction as of a rocket body in which all or most of the stresses are carried by the skin.

MONOPROPELLANT унитарное (однокомпонентное) топливо.

A rocket propellant consisting of a single substance, especially a liquid, capable of producing a heated jet without the addition of a second substance (used attributively in phrases such as **monopropellant rocket** or **motor, monopropellant rocket fuel).**

MULTIPLE (STAGE) ROCKET многоступенчатая ракета.

A vehicle having two or more rocket units, each unit firing after one in back of it has exhausted its propellant. Normally, each unit or stage is jettisoned after completing its firing. Also called **multiple stage rocket** or infrequently a **step rocket.**

MULTIPROPELLANT многокомпонентное топливо.

A rocket propellant consisting of two or more substances fed separately to the combustion chamber.

MULTI-STAGE ROCKET *See* **multiple rocket.**

N

NOSE CONE головная (носовая) часть, головной конус.

The cone-shaped leading end of a rocket vehicle, consisting (a) of a chamber or chambers in which a satellite, instruments, animals, plants, or auxiliary equipment may be carried and (b) of an outer surface built to withstand high temperatures generated by aerodynamic heating t°.

NOZZLE сопло.

Specifically, that part of a rocket thrust chamber assembly in which the gases produced in the chamber are accelerated to high velocities.

NOZZLE THROAT критическое сечение сопла.

The portion of a nozzle with the smallest cross section.

O

ORBIT орбита

The path of a body or particle under the influence of gravitational or other force. Orbit is commonly used to designate a closed path and a trajectory to denote a path which is not closed. (Thus **the trajectory of a rocket, but an orbit of a satellite**).

OVEREXPANDING NOZZLE сопло с перерасширением.

A nozzle in which the fluid is expanded to a lower pressure than the external pressure. (An overexpanding nozzle has an extra area larger than the optimum).

OXIDIZER окислитель.

Specifically, a substance (not necessarily containing oxygen) that supports the combustion of fuel or propellant.

P

PACKAGE блок, узел.

Any assembly or apparatus, complete in itself or practically so, identifiable as a unit and readily available for use or installation.

PATH проекция орбиты спутника на поверхность Земли.

Of a satellite, the projection of the orbital plane on the Earth's surface.

PAYLOAD полезная нагрузка.

1. Originally, the revenue-producing portion of an aircraft's load e. g. passengers, cargo, mail etc. 2. By extension, that which an aircraft, rocket, or the like carries over and above what is necessary for the operation of the vehicle for its flight.

PERIGEE перигей.

That orbital point nearest the Earth when the Earth is the center of attraction. The orbital point farthest from the Earth is called apogee. Perigee and apogee are used by some writers in referring to orbits of satellites, especially artificial satellites, around any planet or satellite, thus avoiding coinage of new terms for each planet and Moon.

PERIHELION перигелий.

That point in a solar orbit which is nearest the Sun. That orbital point farthest from the Sun is called **aphelion.**

PHOTON ENGINE фотонный двигатель.

A projected type of reaction engine in which thrust would be obtained from a stream of electromagnetic radiation.

PHOTON ROCKET фотонная ракета.

A photon engine; a rocket vehicle powered by a photon engine.

PITCH тангаж.

Of a vehicle, an angular displacement about an axis parallel to the lateral axis of the vehicle.

PLASMA плазма.

An electrically conductive gas, comprised by neutral particles, ionized particles and free electrons but which, taken as a whole, is electrically neutral. A plasma is further characterized by relatively large intermolecular distances, large amount of energy stored in the internal energy levels of the particles and the presence of plasma sheath at all boundaries of the plasma. Plasmas are sometimes referred to as a fourth state of matter.

PLASMA ROCKET ракета с плазменным двигателем.
A rocket using a plasma engine. Also called **electromagnetic rocket.**

PLASMA SHEATH плазменная оболочка.
The boundary layer of charged particles between a plasma and its surrounding walls, electrodes, or other plasmas.

POWER PACKAGE силовая установка, силовой агрегат.
An engine together with its accessories ready for quick installation.

POWER PLANT силовая установка.
The complete assemblage or installation of engine or engines with accessories that generates the motive power for a selfpropelled vehicle or vessel such as an aircraft, rocket etc.

PRESSURIZATION герметизация.
The process of producing pressures higher than ambient as in a **pressurized cabin.**

PRESTAGE предварительная (первая) ступень.
A step in the action of igniting a large liquid rocket taken prior to the ignition of the fuel flow and consisting of igniting a partial flow of propellants into thrust chamber. Also called **preliminary stage.**

PROGRAM программа.
In computer operation a plan for the solution of a problem.

R

RADAR (*From* **radio detection and ranging)** радиолокатор.
A method, system or technique of using beamed reflected and timed radio waves for detecting, locating or tracking objects, measuring altitudes etc.

RANGE полигон.
An area over which rockets are fired for testing as **missile range.**

RECOVERABLE спасаемый (возвращаемый).
Of a rocket vehicle or one of its parts: so designed or equipped as to be located after flight and recovered with or without damage.

RECOVERY CAPSULE спасаемая (возвращаемая) капсула.
A capsule designed to be recovered after re-entry.

RECOVERY PACKAGE спасаемый (возвращаемый) контейнер.
A package attached to a re-entry or other body designed for recovery containing devices intended to locate the body after impact. This package may, for example, release a balloon that will buoy up a re-entry body (if it impacts in water) and serve as a radio beacon or light.

RE-ENTRY вход (возвращение) в плотные слои атмосферы.
The event occurring when a spacecraft or other object comes back into the sensible atmosphere after being rocketed to higher altitudes; the action involved in this event.

RE-ENTRY NOSE CONE головная часть ракеты, рассчитанная на возвращение в плотные слои атмосферы.
A nose cone designed especially for re-entry, consisting of one or more chambers protected by an outer shield.

RE-ENTRY TRAJECTORY траектория входа в плотные слои атмосферы.
That part of a rockets trajectory that begins at re-entry and ends

at target or at the surface. If the rocket is unguided at re-entry its re-entry trajectory is ballistic in character.

RE-ENTRY VEHICLE летательный аппарат, возвращаемый в плотные слои атмосферы.

Any payload carrying vehicle designed to leave the sensible atmosphere and then return through it to the Earth. This term applies both to return vehicles from orbital or space payloads and to boost-glide vehicle.

REMOTE CONTROL дистанционное управление.

Control of an operation from a distance, especially by means of electricity or electronics. A controlling switch, lever, or other device used in this kind of control as in **remote control armament, remote control switch.**

RENDEZVOUS встреча, рандеву; место встречи.

1. The event of two or more objects meeting with zero relative velocity at a preconceived time and place. 2. The point in space at which such an event takes place or is to take place. A rendezvous would be involved, for example, in servicing or resupplying a space station.

RESTART повторный запуск (ракетного двигателя).

Specifically, the act of firing a stage of a rocket after a previous powered flight and a coast phase in a parking orbit.

RESTRICTED PROPELLANT бронированный твердотопливный заряд.

A solid propellant having only a portion of its surface exposed for burning, the other surface being covered by an inhibitor.

RESTRICTOR бронирующее покрытие.

In solid-propellant rockets, a layer of fuel containing no oxidizer or of noncombustible material adhered to the surface of the propellant so as to prevent burning in that region.

RETROPACK тормозная двигательная установка.

A rocket unit built into or strapped to a spacecraft that provides retrothrust.

RETROROCKET тормозная ракета.

A rocket fitted on or in a spacecraft, satellite or the like to produce thrust opposed to forward motion.

RETROTHRUST отрицательная (обратная) тяга.

Thrust used for braking maneuver; reverse thrust.

ROCKET ракета.

A projectile, pyrotechnical device or flying vehicle propelled by a rocket engine.

ROCKET AIRPLANE самолет с ракетным двигателем.

An airplane using a rocket or rockets for its chief or only propulsion.

ROCKET ENGINE ракетный двигатель.

A reaction engine that contains within itself or carries along with itself, all the substances necessary for its operation or for the consumption or combustion of its fuel, not requiring intake of any outside substance and hence capable of operation in outerspace. Also called **rocket motor.** Chemical rocket engines contain or carry along their own fuel and oxidizer usually in either liquid or solid form and range from simple motors consisting only of a combustion chamber and exhaust nozzle to engines of some complexity incorporating, in

addition, fuel and oxygen lines, pumps, cooling systems, etc. and sometimes having two or more combustion chambers. Experimental rocket motors have used neutral gas, ionized gas and plasmas as propellants.

ROCKET FUEL ракетное горючее.

A fuel either liquid or solid developed for, or used by, a rocket engine.

ROCKET PROPELLANT ракетное топливо; рабочее тело (ядерной ракеты).

1. Any agent used for consumption or combustion in a rocket and from which the rocket derives its thrust, such as a fuel, oxidizer, additive, catalyst, or any compound or mixture of these. 2. The ejected fluid in a nuclear rocket.

ROCKETRY ракетостроение; теория применения ракет.

The science or study of rockets including theory, research, development, experimentation and application; the art or science of using rockets.

ROCKET SHIP летательный аппарат с ракетным двигателем.

An aircraft, space-air vehicle or spacecraft using rocket propulsion.

ROCKET THRUST тяга ракетного двигателя.

The thrust of a rocket engine usually expressed in pounds.

ROCKET VEHICLE ракета-носитель.

A vehicle propelled by a rocket engine used to place a satellite in orbit, place a missile upon target.

ROLL крен.

The act of rolling; rotational or oscillatory movement of an aircraft or similar body about a longitudinal axis through the body — called **roll** for any degree of such rotation.

RP *See* **rocket propellant.**

RUBBER-BASE PROPELLANT твердое топливо на основе каучука.

A solid propellant mixture in which the oxygen supply is obtained from a perchlorate and the fuel is provided by a synthetic rubber latex.

S

SALVO LAUNCH залповый пуск ракет.

Act of launching two or more rockets simultaneously.

SATELLITE искусственный спутник.

1. A manmade object that revolves about a spinal body (around the Earth). 2. Such a body intended and designed for orbiting as distinguished from a companion body that may incidentally also orbit as **the observer actually saw the orbiting rocket rather than the satellite**. 3. An object not yet placed in orbit but designed or expected to be launched into an orbit.

SECTION отсек, секция.

One of the cross-section parts that a rocket vehicle is divided into, each adjoining another at one or both its ends. Usually described by a designating word, as in **nose section, aft section, center section, tail section, thrust section, tank section.**

SENSIBLE ATMOSPHERE ощутимая атмосфера.

That part of the atmosphere that offers resistance to a body passing through it.

SERVOMECHANISM сервомеханизм.

A control system incorporating feedback in which one or more of the system signals represent mechanical motion.

SHOT пуск; полет.

1. An act or instance of firing a rocket especially from the Earth's surface as **the shot carried the rocket 200 miles**. 2. The flight of a rocket, as **the rocket made a 200-mile shot**.

SINGLE-STAGE ROCKET одноступенчатая ракета.

A rocket vehicle provided with a single rocket propulsion system.

SKIRT юбка, нижняя наружная часть ракеты.

The lower outer part of a rocket vehicle.

SOFT LANDING мягкая посадка.

The act of landing on the surface of a planet without damage to any portion of the vehicle or payload except possibly the landing gear.

SOLID PROPELLANT твердое топливо.

Specifically, a rocket propellant in solid form, usually containing both fuel and oxidizer combined or mixed and formed into a monolithic (not powdered or granulated) grain.

SOLID-PROPELLANT ROCKET ENGINE ракетный двигатель твердого топлива.

A rocket engine fueled with a solid propellant. Such motors consist essentially of a combustion chamber containing the propellant and a nozzle for the exhaust jet, although they often contain other components.

SOLID ROCKET ракета твердого топлива.

A rocket that uses a solid propellant.

SOUNDING ROCKET исследовательская (зондирующая, высотная) ракета.

A rocket that carries aloft equipment for making observations of or from upper atmosphere.

SPACE космос; вселенная.

1. Specifically, the part of the universe lying outside the limits of the Earth's atmosphere. 2. More generally, the volume in which all celestial bodies, including the Earth, move.

SPACE-AIR VEHICLE воздушно-космический летательный аппарат.

A vehicle operable either within or above the sensible atmosphere. Also called aerospace vehicle.

SPACECRAFT космический летательный аппарат.

Devices manned and unmanned which are designed to be placed into an orbit about the Earth or into a trajectory to another celestial body.

SPIN ROCKET ракетный двигатель, придающий вращение.

A small rocket that imparts spin to a larger rocket vehicle or spacecraft.

SPIN STABILIZATION стабилизация вращением.

Directional stability of a spacecraft obtained by the action of gyroscopic forces which result from spinning of the body about the axis of symmetry.

STAGE ступень; фаза.

1. A self-propelled separable element of a rocket vehicle. 2. A step

or process through which a fluid passes, especially in compression or expansion.

STAGE-AND-A-HALF полутораступенчатая ракета с отбрасываемыми стартовыми двигателями.

A liquid-propellant rocket of which only part of the propulsion unit falls away from the rocket vehicle during flight, as in the case of booster rockets falling away to leave the sustainer engine to consume remaining fuel.

STAGING сбрасывание (отделение) ступеней.

The process or operation during the flight of a rocket vehicle whereby a full stage or half stage is disengaged from the remaining body and made free to decelerate or be propelled along its own flight path.

STAR TRACKER следящий телескоп системы астронаведения; астроориентатор.

A telescopic instrument on a rocket or other flight borne vehicle that locks onto a celestial body and gives guidance reference to the vehicle during flight.

STATIONARY ORBIT стационарная орбита.

An orbit in which the satellite revolves about the primary at the angular rate at which the primary rotates on its axis. From the primary, the satellite thus appears to be stationary over a point on the primary. A stationary orbit with respect to the Earth is commonly called a **24-hour orbit**.

STEP ROCKET *See* **multiple rocket.**

STORABLE длительного хранения.

Of a liquid, subject to being placed and kept in a tank without benefit of special measures for temperature or pressure control, as in **storable propellant.**

SUBLIMATION сублимация.

The transition of a substance directly from the solid state to the vapour state or vice versa, without passing through the intermediate liquid state.

SUPERSONIC сверхзвуковой.

Of or pertaining to, or dealing with, speeds greater than the acoustic velocity.

SUPERSONIC NOZZLE сверхзвуковое сопло.

A converging-diverging nozzle designed to accelerate a fluid to supersonic speed.

SUSTAINER ENGINE маршевый двигатель.

A rocket engine that maintains the velocity of a rocket vehicle once it has achieved its programmed velocity by use of booster or other engine.

T

TAIL хвост, хвостовая часть.

1. The rear part of a body, as of an aircraft, a rocket etc. 2. The tail surfaces of an aircraft or rocket.

TAKE-OFF взлет, старт.

The action of a rocket vehicle departing from its launch pad.

TANDEM LAUNCH последовательный запуск, запуск двух и более искусственных спутников одной ракетой-носителем.

The launching of two or more satellites using a single launch vehicle.

TANK бак; резервуар.

1. A container incorporated into the structure of a liquid propellant rocket from which a liquid propellant or propellants are fed into the firing chamber or chambers. 2. A container for storage of liquid oxygen, liquid fuel or other liquid propellant unit transferred to the rocket's tanks or some other receptacle.

TANKAGE емкость, суммарная емкость топливных баков.

Of a liquid propellant rocket, the aggregate of the tanks carried by the rocket.

TARGET цель.

Specifically, an object which reflects a sufficient amount of radiated signal to produce an echo signal on detection equipment.

TARGET ACQUISITION обнаружение цели.

The process of optically, manually, mechanically or electronically orienting tracking system in direction and range to lock on a target.

TERMINAL GUIDANCE наведение (управление) на конечном участке траектории.

Guidance from an arbitrary point at which midcourse guidance ends to the destination.

THROTTLING дросселирование.

The varying of the thrust of a rocket engine during powered flight by some technique tightening of fuel lines, changing thrust chamber pressure, pulsed thrust and variation of nozzle expansion are methods to achieve throttling.

THRUST тяга, сила тяги; динамическая составляющая тяги.

The pushing or pulling force developed by an aircraft engine or a rocket engine. Specifically in rocketry $\mathbf{F} = \mathbf{mv}$ where $\mathbf{m}$ is propellant mass flow and $\mathbf{v}$ is exhaust velocity relative to the vehicle. Also called momentum thrust.

THRUST SECTION отсек силовой установки; силовая установка.

1. A section in a rocket vehicle that houses or incorporates the combustion chamber or chambers and nozzles. 2. In loose usage, a propulsion system.

THRUST TERMINATOR устройство сброса тяги, устройство для отсечки двигателя.

A device for ending the thrust in a rocket engine, either through propellant cutoff (in the case of a liquid) or through diverting the flow of gases from the nozzle.

THRUST-TO-WEIGHT RATIO тяговооруженность *(отношение тяги двигателя к весу).*

A quantity used to evaluate engine performance, obtained by dividing the thrust output by the engine weight less fuel. If the pound is used as the unit of measure for thrust and weight, the result is pounds of thrust per pounds of engine.

TRAJECTORY траектория.

In general, the path traced by any body moving as a result of an externally applied force, considered in three dimensions. (Trajectory is sometimes used to mean flight path or orbit, but orbit usually means a closed path and trajectory.)

TRANSCEIVER приемопередатчик.

A combination transmitter and receiver in a single housing with some components being used by both units.

TRAP улавливатель невырабатываемого топлива.

A part of a solid-propellant rocket engine used to prevent the loss of unburned propellant through the nozzle.

T-TIME момент пуска.

Any specific time, minus or plus as referenced to zero or launch time, during a countdown sequence that is intended to result in the firing of a rocket propulsion unit that launches a rocket vehicle.

U

ULLAGE свободное пространство в баке (над зеркалом топлива).

The amount that a container, such as a fuel tank, lacks of being full.

ULLAGE ROCKET ракетный двигатель системы наддува баков.

A small rocket used in space to impart an acceleration to a tank system to insure that the liquid propellants collect in the tank in such a manner as to flow properly into pumps or thrust chamber.

ULTRASONIC ультразвуковой, сверхзвуковой.

In acoustics, of or pertaining to frequencies above those that affect the human ear, i. e. more than 20,000 vibrations per second.

UMBILICAL CORD кабель линии коммуникации; цепь наземного питания.

Any of the servicing electrical or fluid lines between the ground or a tower and an uprighted rocket vehicle before the launch. Often shortened to umbilical.

UMBILICAL TOWER мачта наземного питания.

A vertical structure supporting the umbilical cords running into a rocket in launching position.

UPPER STAGE верхняя ступень.

A second or later stage in a multistage rocket.

V

VANE лопатка, флюгер; руль.

A thin and more or less flat object intended to aline itself with a stream or flow in a manner similar to that of the common weathercock as (a) a device that projects ahead of an aircraft to sense gusts or other actions of the air so as to create impulses or signals that are transmitted to the control system to stabilize the aircraft; (b) a fixed or movable surface used to control or give stability to a rocket.

VARIABLE-AREA EXHAUST NOZZLE выхлопное сопло регулируемого сечения.

On a jet engine, an exhaust nozzle of which the exhaust exit opening can be varied in area by means of some mechanical device, permitting variations in the jet velocity.

VEHICLE транспортное средство; летательный аппарат; ракета.

Specifically, a structure, machine, or device, such as an aircraft or rocket, designed to carry a burden through air or space; more

restrictively, a rocket vehicle. (This word has acquired its specific meaning owing to the need for a term to embrace aircraft, rockets, and all other flying craft and has more currency than other words used in this meaning).

VERNIER ENGINE верньерный двигатель.

A rocket engine of small thrust used primarily to obtain a fine adjustment in the velocity and trajectory of a rocket vehicle just after the thrust cutoff of the last sustainer engine and used secondarily to add thrust to a booster or sustainer engine. Also called **vernier rocket.**

W

WALK AROUND BOTTLE индивидуальный кислородный баллон.

A personal supply of oxygen for the use of crew members when temporarily disconnected from the crafts system.

WARHEAD боевая часть; головная часть с зарядным устройством.

Originally the part of a missile carrying the explosive, chemical or other charge intended to damage the enemy. By extension the term is sometimes used as synonymous with **payload** or **nose cone.**

WARMUP TIME период подогрева.

The time interval required for a gyro to reach specified performance from the instant is energized.

Y

YAW рыскание; угол рыскания.

1. The rotational or oscillatory movement of an aircraft, rocket or the like about a vertical axis. 2. The amount of this movement, i. e. the angle of yaw.

YAW AXIS ось рыскания.

A vertical axis through an aircraft, rocket, or similar body about which the body yaws. It may be a body, wind or stability axis. Also called a **yawing axis.**

GLOSSARY

DIVISION TWO: EFFECTS OF NUCLEAR WEAPONS; COMBAT EMPLOYMENT

A

A-BOMB атомная бомба.

An abbreviation for **atomic bomb.**

ABSORBED DOSE доза поглощенной радиации.

The amount of energy imparted by nuclear (or ionizing) radiation to unit mass of absorbing material. The unit is the rad. *See* **dose, rad.**

ABSORPTION поглощение.

As applied to gamma (or X-) radiation it is strictly the process (or processes) resulting in the transfer of energy by the radiation to an absorbing material through which it passes. In this sense, absorption involves only the photoelectric effect and pair production. However, the term is frequently used interchangeably with attenuation, which includes the Compton effect; absorption then includes both the removal and scattering of photons. *See* **attenuation, Compton effect, pair production, photoelectric effect, scattering.**

ABSORPTION COEFFICIENT коэффициент поглощения.

A number characterizing the ability of a given material to absorb (or attenuate) radiations of a specified energy. The linear absorption coefficient expresses this ability per unit thickness and is stated in units of reciprocal length (or thickness). The mass absorption coefficient is equal to the linear absorption coefficient divided by the density of the absorbing material; it is a measure of the absorption ability per unit mass.

ACTIVATION DETECTOR активационный детектор.

A material used to determine neutron flux or density by virtue of the radioactivity induced in it as a result of neutron capture. *See* **neutron flux, threshold detector.**

ACTUAL GROUND ZERO действительный эпицентр взрыва.

The point on the earth's surface below at or above the center of an actual nuclear burst.

AGZ *See* **actual ground zero.**

AIR BURST воздушный взрыв.

The explosion of a nuclear weapon at such a height that the expanding fireball does not touch the earth's surface when the luminosity is a maximum (in the second pulse).

ALPHA PARTICLE альфа-частица.

A particle emitted spontaneously from the nuclei of some radioactive elements. It is identical with a helium nucleus, having a mass

of four units and an electric charge of two positive units. *See* **radioactivity.**

ATOM атом.

The smallest (or ultimate) particle of an element that still retains the characteristics of that element. Every atom consists of a positively charged central nucleus, which carries nearly all the mass of the atom, surrounded by a number of negatively charged electrons, so that the whole system is electrically neutral. *See* **element, electron, nucleus.**

ATOMIC BOMB (or **WEAPON)** атомная бомба (атомное оружие).

A term sometimes applied to a nuclear weapon utilizing fission energy only. *See* **fission, nuclear weapon.**

ATOMIC CLOUD атомное облако, облако атомного взрыва.

See **radioactive cloud.**

ATOMIC NUMBER атомный номер.

See **nucleus.**

ATOMIC WEIGHT атомный вес.

The relative weight of an atom of the given element. As a basis of reference, the atomic weight of the common isotope of carbon (carbon 12) is taken to be exactly 12; the atomic weight of hydrogen (the lightest element) is then 1.008. Hence, the atomic weight of any element is approximately the weight of an atom of that element relative to the weight of a hydrogen atom.

ATTENUATION рассеивание.

Decrease in intensity of a signal, beam, or wave as a result of absorption of energy and of scattering out of the path of a detector, but not including the reduction due to geometric spreading, i. e., the inverse square of distance effect. *See* **absorption, inverse square law.**

B

BACKGROUND RADIATION фоновое излучение.

Nuclear (or ionizing) radiations arising from within the body and from the surroundings to which individuals are always exposed. The main sources of the natural background radiation are potassium-40 in the body, potassium-40 and thorium, uranium, and their decay products (including radium) present in rocks, and cosmic rays.

BASE SURGE базисная волна.

A cloud which rolls outward from the bottom of the column produced by a subsurface explosion. For underwater bursts the visible surge is, in effect, a cloud of liquid (water) droplets with the property of flowing almost as if it were a homogeneous fluid. After the water evaporates, an invisible base surge of small radioactive particles may persist. For subsurface land bursts the surge is made up of small solid particles but it still behaves like a fluid. A soft earth medium favors base surge formation in an underground burst.

BETA PARTICLE бета-частица.

A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most (if not all) of the direct fission products emit (negative) beta particles. Physically, the beta particle is identical with an electron moving at high velocity. *See* **electron, fission products, radioactivity.**

BIOLOGICAL HALF-TIME биологический период полувыделения.

The time required for the amount of a specified element which has entered the body (or a particular organ) to be decreased to half of its initial value as a result of natural, biological elimination processes.

BLAST LOADING ударная (динамическая) нагрузка.

The loading (or force) on an object caused by the air blast from an explosion striking and flowing around the object. It is a combination of overpressure (or diffraction) and dynamic pressure (or drag) loading.

BLAST SCALING LAWS законы подобия для ударной волны.

Formulas which permit the calculation of the properties, e. g., overpressure, dynamic pressure, time of arrival, duration, etc., of a blast wave at any distance from an explosion of specified energy from the known variation with distance of these properties for a reference explosion of known energy, e. g., of 1 kiloton.

BLAST WAVE ударная волна.

A pulse of air in which the pressure increases sharply at the front, accompanied by winds, propagated continuously from an explosion. *See* **shock wave.**

BOMB DEBRIS продукты взрыва.

See **weapon debris.**

BREAKAWAY отрыв (ударной волны).

The onset of a condition in which the shock front (in the air) moves away from the exterior of the expanding fireball produced by the explosion of a nuclear (or atomic) weapon. *See* **fireball, shock front.**

BURST взрыв.

Explosion or detonation. *See* **air burst, high-altitude burst, surface burst, underground burst, underwater burst.**

C

CALL MISSION огонь по заявке.

A type of (fire) mission which is not requested sufficiently in advance of the desired time of execution to permit detailed planning.

CEP *See* **circular error probable.**

CHEMICAL DOSIMETER химический дозиметр.

A self-indicating device for determining total (or accumulated) radiation exposure dose based on color changes accompanying chemical reactions induced by the radiation.

CIRCULAR ERROR PROBABLE среднее вероятное отклонение.

An indicator of the accuracy of a missile used as a factor in determining probable damage to a target. It is the radius of a circle within which half of the missiles are expected to fall.

CLEAN WEAPON „чистое" оружие (бомба).

One in which measures have been taken to reduce the amount of residual radioactivity relative to a "normal" weapon of the same energy yield.

CLOUD COLUMN дымовой столб, столб пыли и дыма.

The visible column of smoke extending upward from the point of burst of a nuclear (or atomic) weapon.

CLOUD PHENOMENA явления, сопровождающие образование облака.

See **base surge, cloud column, fallout, fireball, radioactive cloud.**

COLUMN (or PLUME) полый столб, султан.

A hollow cylinder of water and spray thrown up from an underwater burst of a nuclear (or atomic) weapon, through which the hot, high-pressure gases formed in the explosion are vented to the atmosphere. A somewhat similar column of dirt is formed in an underground explosion.

COMPTON EFFECT эффект Комптона.

The scattering of photons (of gamma or X-rays) by the orbital electrons of atoms. In a collision between a (primary) photon and an electron, some of the energy of the photon is transferred to the electron which is generally ejected from the atom. Another (secondary) photon, with less energy, then moves off in a new direction at an angle to the direction of motion of the primary photon.

COMPTON ELECTRON комптоновский электрон (электрон отдачи).

An electron of increased energy ejected from an atom as the result of a Compton interaction with a photon. *See* **Compton effect.**

CONDENSATION CLOUD конденсационное облако.

A mist or fog of minute water droplets which temporarily surrounds the fireball following a nuclear (or atomic) detonation in a comparatively humid atmosphere. The expansion of the air in the negative phase of the blast wave from the explosion results in a lowering of the temperature, so that condensation of water vapor present in the air occurs and a cloud forms. The cloud is soon dispelled when the pressure returns to normal and the air warms up again.

CONTACT SURFACE BURST контактный наземный взрыв.

See **surface burst.**

CONTAINED UNDERGROUND BURST „сдержанный" подземный ядерный взрыв (взрыв, при котором продукты деления в атмосферу не проникают).

An underground detonation at such a depth that none of the radioactive residues escape through the surface of the ground.

CONTAMINATION заражение.

The deposit of radioactive material on the surfaces of structures, areas, objects, or personnel, following a nuclear (or atomic) explosion. This material generally consists of fallout in which fission products and other weapon debris have become incorporated with particles of dirt, etc. Contamination can also arise from the radioactivity induced in certain substances by the action of neutrons from a nuclear explosion. *See* **decontamination, fallout, induced radioactivity, weapon debris.**

CRATER воронка от взрыва (ядерного боеприпаса).

The pit, depression, or cavity formed in the surface of the earth by an explosion. The apparent crater is the depression which is seen after the burst; it is smaller than the true crater, i. e., the cavity actually formed by the explosion, because it is covered with a layer of loose earth, rock, etc. In a deep underground burst when there is no rupture of the surface, the resulting cavity is called a camouflet.

CRITICAL MASS критическая масса.

The minimum mass of a fissionable material that will just main-

tain a fission chain reaction under precisely specified conditions, such as the nature of the material and its purity, the nature and thickness of the tamper (or neutron reflector), the density (or compression), and the physical shape (or geometry). For an explosion to occur, the system must be supercritical, i. e., the mass of material must exceed the critical mass under the existing conditions. *See* **supercritical.**

CUBE ROOT LAW закон кубического корня.

A scaling law applicable to many blast phenomena. It relates the time and distance at which a given blast effect is observed to the cube root of the energy yield of the explosion.

CURIE кюри.

A unit of radioactivity; it is the quantity of any radioactive species in which 3.700×10^{10} nuclear disintegrations occur per second. The gamma curie is sometimes defined correspondingly as the quantity of material in which this number of gamma-ray photons are emitted per second.

D

DAMAGE CRITERIA критерий разрушений и поражения.

Standards or measures used in estimating specific levels of damage.

DECAY (or **RADIOACTIVE DECAY)** распад или радиоактивный распад.

The decrease in activity of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation. *See* **half-life, radioactivity.**

DECONTAMINATION дезактивация.

The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface so as to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of natural decay; and (3) covering the contamination so as to attenuate the radiation emitted. Radioactive material removed in process (1) must be disposed of by burial on land or at sea, or in other suitable way.

DELAYED FALLOUT позднее выпадение (выпадение в пределах всего земного шара).

See **fallout.**

DEUTERIUM дейтерий.

An isotope of hydrogen of mass 2 units; it is sometimes referred to as heavy hydrogen. It can be used in thermonuclear fusion reactions for the release of energy. Deuterium is extracted from water which always contains 1 atom of deuterium to about 6,500 atoms of ordinary (light) hydrogen. *See* **fusion, thermonuclear.**

DIFFRACTION дифракция.

The bending of waves around the edges of objects. In connection with a blast wave impinging on a structure, diffraction refers to the passage around and envelopment of the structure by the blast wave. Diffraction loading is the force (or loading) on the structure during the envelopment process.

DIRTY WEAPON „грязное“ ядерное оружие (бомба).

One which produces a larger amount of radioactive residues than a "normal" weapon of the same yield. *See* **salted weapon.**

DOME купол.

The mound of water spray thrown up into the air when the shock wave from an underwater detonation of a nuclear (or atomic) weapon reaches the surface.

DOSE доза.

A (total or accumulated) quantity of ionizing (or nuclear) radiation. The term dose is often used in the sense of the exposure dose, expressed in roentgens, which is a measure of the total amount of ionization that the quantity of radiation could produce in air. This should be distinguished from the absorbed dose, given in reps or rads, which represents the energy absorbed from the radiation per gram of specified body tissue. Further, the biological dose, in rems, is a measure of the biological effectiveness of the radiation exposure. *See* **rad, RBE, rem, roentgen.**

DOSE RATE мощность дозы, уровень радиации.

As a general rule, the amount of ionizing (or nuclear) radiation to which an individual would be exposed or which he would receive per unit of time. It is usually expressed as roentgens, rads, or rems per hour or in multiples or submultiples of these units, such as milliroentgens per hour. The dose rate is commonly used to indicate the level of radioactivity in a contaminated area. *See* **survey meter.**

DOSE RATE CONTOUR контур (граница) с определенной мощностью дозы.

Lines drawn on an overlay or map connecting points of equal radiation dose rates which are expressed in terms of rads per hour at a specified time.

DOSIMETER дозиметр.

An instrument for measuring and registering total accumulated exposure to ionizing radiations. *See* **dosimetry.**

DOSIMETRY дозиметрия.

The theory and application of the principles and techniques involved in the measurement and recording of radiation doses and dose rates. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made. *See* **chemical dosimeter, film badge, survey meter.**

DRAG LOADING нагрузка торможения.

The force on an object or structure due to the transient winds accompanying the passage of a blast wave. The drag pressure is the product of the dynamic pressure and the drag coefficient which is dependent upon the shape (or geometry) of the structure or object. *See* **dynamic pressure.**

DYNAMIC PRESSURE динамическое давление.

The air pressure which results from the mass air flow (or wind) behind the shock front of a blast wave. It is equal to the product of half the density of the air through which the blast wave passes and the square of the particle (or wind) velocity behind the shock front as it impinges on the object or structure.

E

EARLY FALLOUT раннее (местное) выпадение (радиоактивных осадков). *See* **fallout.**

ELECTROMAGNETIC RADIATION электромагнитное излучение.

A traveling wave motion resulting from oscillating magnetic and electric fields. Familiar electromagnetic radiations range from X-rays (and gamma rays) of short wave length, through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wave length. All electromagnetic radiations travel in a vacuum with the velocity of light. *See* **photon.**

ELECTRON электрон.

A particle of very small mass, carrying a unit negative or positive charge. Negative electrons, surrounding the nucleus, are present in all atoms; their number is equal to the number of positive charges (or protons) in the particular nucleus. The term electron, where used alone, commonly refers to these negative electrons. A positive electron is usually called a positron, and a negative electron is sometimes called a **negatron.** *See* **beta particle.**

ELECTRON VOLT электрон-вольт (эв).

The energy imparted to an electron when it is moved through a potential difference of 1 volt. It is equivalent to 1.6×10^{-12} erg.

ELEMENT элемент.

One of the distinct, basic varieties of matter occurring in nature which, individually or in combination, compose substances of all kinds. Approximately ninety different elements are known to exist in nature and several others, including plutonium, have been obtained as a result of nuclear reactions with these elements.

ENIWETOK PROVING GROUNDS испытательный полигон на атолле Эниветок.

An area in the Marshall Islands, including the Eniwetok and Bikini Atolls, used for nuclear (or atomic) tests. Formerly referred to as the Pacific Proving Grounds.

EV *See* **electron volt.**

F

FALLOUT выпадение (радиоактивных осадков).

The process or phenomenon of the fallback to the earth's surface of particles contaminated with radioactive material from the radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself. The early (or local) fallout is defined, somewhat arbitrarily, as those particles which reach the earth within 24 hours after a nuclear explosion. The delayed (or worldwide) fallout consists of the smaller particles which ascend into the upper troposphere and into the stratosphere and are carried by winds to all parts of the earth. The delayed fallout is brought to earth, mainly by rain and snow, over extended periods ranging from months to years.

FILM BADGE фотопленочный дозиметр.

A small metal or plastic frame, in the form of a badge, worn by personnel, and containing X-ray (or similar photographic) film for estimating the total amount of ionizing (or nuclear) radiation to which an individual has been exposed.

FIREBALL огненный шар.

The luminous sphere of hot gases which forms a few millionths of a second after a nuclear (or atomic) explosion as the result of the

absorption by the surrounding medium of the thermal X-rays emitted by the extremely hot (several tens of millions degrees) weapon residues. The exterior of the fireball in air is initially sharply defined by the luminous shock front and later by the limits of the hot gases themselves (radiation front). *See* **breakaway.**

FIRE STORM огненный шторм.

Stationary mass fire, generally in built-up urban areas, generating strong, inrushing winds from all sides; the winds keep the fires from spreading while adding fresh oxygen to increase their intensity.

FISSION деление.

The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy. The most important fissionable materials are uranium-235 and plutonium-239.

FISSION FRACTION доля энергии термоядерного взрыва, получаемая за счет реакции деления.

The fraction (or percentage) of the total yield of a nuclear weapon which is due to fission. For thermonuclear weapons the average value of the fission fraction is about 50 per cent.

FISSION PRODUCTS продукты деления.

A general term for the complex mixture of substances produced as a result of nuclear fission. A distinction should be made between these and the direct fission products or fission fragments which are formed by the actual splitting of the heavy-element nuclei. Something like 80 different fission fragments result from roughly 40 different modes of fission of a given nuclear species, e. g., uranium-235 or plutonium-239. The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains about 200 different isotopes of 36 elements.

FLASH BURN световой ожог.

A burn caused by excessive exposure (of bare skin) to thermal radiation. *See* **thermal radiation.**

FRACTIONAL DAMAGE частичное поражение (степень поражения или разрушения).

A fraction or percentage of the elements of a target which may be damaged or become casualties from a nuclear attack.

FRACTIONATION фракционирование.

Any one of several processes, apart from radioactive decay, which results in change in the composition of the radioactive weapon debris. As a result of fractionation, the delayed fallout generally contains relatively more of strontium-90 and cesium-137, which have gaseous precursors, than does the early fallout from a surface burst.

FREE AIR OVERPRESSURE (or **FREE FIELD OVERPRESSURE)** избыточное давление в прямой воздушной ударной волне.

The unreflected pressure, in excess of the ambient atmospheric pressure, created in the air by the blast wave from an explosion.

FUSION синтез.

The process whereby the nuclei of light elements, especially those of the isotopes of hydrogen, namely, deuterium and tritium, combine to form the nucleus of a heavier element with the release of substantial amounts of energy. *See* **thermonuclear.**

G

GAMMA RAYS (or RADIATIONS) гамма-лучи (излучение).

Electromagnetic radiations of high energy originating in atomic nuclei and accompanying many nuclear reactions, e. g., fission, radioactivity, and neutron capture. Physically, gamma rays are identical with X-rays of high energy, the only essential difference being that the X-rays do not originate from atomic nuclei, but are produced in other ways, e. g., by slowing down (fast) electrons of high energy. *See* **electromagnetic radiation, X-rays.**

GENETIC EFFECT генетические последствия.

The effect (of nuclear radiation, in particular) of producing changes (mutations) in the hereditary components (genes) in the germ cells present in the reproductive organs (gonads). A mutant gene causes changes in the next generation which may or may not be apparent.

GROUND ZERO эпицентр (ядерного взрыва).

The point on the surface of land or water vertically below or above the center of a burst of a nuclear (or atomic) weapon; frequently abbreviated to GZ. For a burst over or under water, the term surface zero should preferably be used.

GUN-TYPE WEAPON ядерное устройство пушечного типа.

A device in which two or more pieces of fissionable material, each less than a critical mass, are brought together very rapidly so as to form a supercritical mass which can explode as the result of a rapidly expanding fission chain.

GZ *See* **ground zero.**

H

HALF-LIFE период полураспада.

The time required for the activity of a given radioactive species to decrease to half of its initial value due to radioactive decay. The half-life is a characteristic property of each radioactive species and is independent of its amount or condition. The effective half-life of a given isotope is the time in which the quantity in the body will decrease to half as a result of both radioactive decay and biological elimination. *See* **biological half-time.**

HALF-RESIDENCE TIME период „половинного оседания".

As applied to delayed fallout, it is the time required for the amount of weapon debris deposited in a particular part of the atmosphere, e. g., stratosphere or troposphere, to decrease to half of its initial value.

HALF-VALUE THICKNESS слой половинного ослабления.

The thickness of a given material which will absorb half the gamma radiation incident upon it. This thickness depends on the nature of the material — it is roughly inversely proportional to its density — and also on the energy of the gamma rays.

H-BOMB водородная бомба.

An abbreviation for hydrogen bomb.

HEIGHT OF BURST высота взрыва.

The height above the earth's surface at which a bomb is detonated in the air. The optimum height of burst for a particular target (or area) is that at which it is estimated a weapon of a specified

energy yield will produce a certain desired effect over the maximum possible area.

HIGH-ALTITUDE BURST высотный взрыв.

This is defined, somewhat arbitrarily, as a detonation at an altitude over 100,000 feet. Above this level the distribution of the energy of the explosion between blast and thermal radiation changes appreciably with increasing altitude due to changes in the fireball phenomena.

HOT SPOT участок с высоким уровнем радиации.

Region in a contaminated area in which the level of radioactive contamination is somewhat greater than in neighboring regions in the area.

HYDROGEN BOMB (or **WEAPON**) водородная бомба (водородное оружие).

A term sometimes applied to nuclear weapons in which part of the explosive energy is obtained from nuclear fusion (or thermonuclear) reactions.

HYPOCENTER гипоцентр.

A term sometimes used for ground zero. *See* **ground zero.**

I

IMPLOSION WEAPON атомное оружие имплозивного типа.

A device in which a quantity of fissionable material, less than a critical mass, has its volume suddenly decreased by compression, so that it becomes supercritical and an explosion can take place. The compression is achieved by means of a spherical arrangement of specially fabricated shapes of ordinary high explosive which produce an inwardly-directed implosion wave, the fissionable material being at the center of the sphere. *See* **supercritical.**

IMPULSE (PER UNIT AREA) импульс (количество световой энергии, приходящееся на единицу площади).

The product of the overpressure (or dynamic pressure) from the blast wave of an explosion and the time during which it acts at a given point. More specifically, it is the integral, with respect to time, of the overpressure (or dynamic pressure), the integration being between the time of arrival of the blast wave and that at which the overpressure (or dynamic pressure) returns to zero at the given point.

INDUCED RADIOACTIVITY наведенная радиоактивность.

Radioactivity produced in certain materials as a result of nuclear reactions, particularly the capture of neutrons, which are accompanied by the formation of unstable (radioactive) nuclei. The activity induced by neutrons from a nuclear (or atomic) explosion in materials containing the elements sodium, manganese, silicon, or aluminum may be significant.

INFRARED инфракрасный.

Electromagnetic radiations of wave length between the longest visible red (7,000 Angstroms or 7×10^{-4} millimeter) and about 1 millimeter. *See* **electromagnetic radiation.**

INITIAL NUCLEAR RADIATION начальная ядерная радиация.

Nuclear radiation (essentially neutrons and gamma rays) emitted from the fireball and the cloud column during the first minute after a nuclear (or atomic) explosion. The time limit of one minute is set,

somewhat arbitrarily, as that required for the source of part of the radiations (fission products, etc., in the radioactive cloud) to attain such a height that only insignificant amounts reach the earth's surface. *See* **residual nuclear radiation.**

INTEGRATED NEUTRON FLUX суммарный поток нейтронов.

The product of neutron flux and time, expressed in units of neutrons per square centimeter. It is a measure of neutron exposure dose. *See* **dose, neutron flux.**

INTENSITY интенсивность.

The energy (of any radiation) incident upon (or flowing through) unit area, perpendicular to the radiation beam, in unit time. The intensity of thermal radiation is generally expressed in calories per square centimeter per second falling on a given surface at any specified instant. As applied to nuclear radiation, the term intensity is sometimes used, rather loosely, to express the exposure dose rate at a given location, e. g., in roentgens (or milliroentgens) per hour.

INTERNAL RADIATION внутренняя радиация.

Nuclear radiation (alpha and beta particles and gamma radiation) resulting from radioactive substances in the body. Important sources are iodine-131 in the thyroid gland, and strontium-90 and plutonium-239 in the bone.

INVERSE SQUARE LAW закон обратного квадратного подобия.

The law which states that when radiation (thermal or nuclear) from a point source is emitted uniformly in all directions, the amount received per unit area at any given distance from the source, assuming no absorption, is inversely proportional to the square of that distance.

IONIZATION ионизация.

The separation of a normally electrically neutral atom or molecule into electrically charged components. The term is also employed to describe the degree or extent to which this separation occurs. In the sense used in this book, ionization refers especially to the removal of an electron (negative charge) from the atom or molecule, either directly or indirectly, leaving a positively charged ion. The separated electron and ion are referred to as an ion pair.

IONIZING RADIATION ионизирующая радиация.

Electromagnetic radiation (gamma rays or X-rays) or particulate radiation (alpha particles, beta particles, neutrons, etc.) capable of producing ions, i. e., electrically charged particles, directly or indirectly, in its passage through matter.

IONOSPHERE ионосфера.

The region of the atmosphere, extending from roughly 40 to 250 miles altitude, in which there is appreciable ionization. The presence of charged particles in this region profoundly affects the propagation of long wave length electromagnetic radiation (radio and radar waves).

ION PAIR пара ионов.

See **ionization.**

ISOTOPES изотопы.

Forms of the same element having identical chemical properties but differing in their atomic masses (due to different numbers of neutrons in their respective nuclei) and in their nuclear properties, e. g., radioactivity, fission, etc. For example, hydrogen has three iso-

topes, with masses of 1 (hydrogen), 2 (deuterium), and 3 (tritium) units, respectively. The first two of these are stable (nonradioactive), but the third (tritium) is a radioactive isotope. Both of the common isotopes of uranium, with masses of 235 and 238 units, respectively, are radioactive, emitting alpha particles, but their half lives are different. Furthermore, uranium 235 is fissionable by neutrons of all energies, but uranium 238 will undergo fission only with neutrons of high energy. *See* **nucleus.**

K

KEV *See* **kilo-electron volt.**

KILO-ELECTRON VOLT килоэлектрон-вольт.

An amount of energy equal to 1,000 electron volts.

KILOTON ENERGY количество энергии, освобождающейся при ядерном взрыве, эквивалентное количеству энергии, выделяющейся при взрыве 1000 тонн тротила.

The energy of a nuclear (or atomic) explosion which is equivalent to that produced by the explosion of 1 kiloton (i. e., 1,000 tons) of TNT, i. e., 10^{12} calories or 4.2×10^{19} ergs.

L

LINEAR ABSORPTION COEFFICIENT линейный коэффициент поглощения.

See **absorption coefficient.**

LIP HEIGHT высота подъема грунта *(при взрыве)*.

The height above the original surface to which earth is piled around the crater formed by an explosion. *See* **crater.**

LOADING нагрузка.

The force on an object or structure or element of a structure. The loading due to blast is equal to the net pressure in excess of the ambient value multiplied by the area of the loaded object, etc.

M

MACH FRONT фронт Маха.

See **Mach stem.**

MACH REGION область Маха.

The region on the surface at which the Mach stem has formed as the result of a particular explosion in the air.

MACH STEM головная ударная волна, волна Маха.

The shock front formed by the fusion of the incident and reflected shock fronts from an explosion. The term is generally used with reference to a blast wave, propagated in the air, reflected at the surface of the earth. The Mach stem is nearly perpendicular to the reflecting surface and presents a slightly convex (forward) front. The Mach stem is also called the Mach front.

MASS ABSORPTION COEFFICIENT массовый коэффициент поглощения.

See **absorption coefficient.**

MASS NUMBER массовое число.

See **nucleus.**

MAXIMUM PERMISSIBLE DOSAGE максимальная допустимая доза.

The weekly radiation dosage set up as a safe maximum for personnel working under nonemergency conditions.

MAXIMUM PERMISSIBLE DOSE максимальная допустимая доза.

That radiation dose which a military commander or other appropriate authority may prescribe as the limiting cumulative radiation dose to be received over a specific period of time by members of his command consistent with current operational military considerations.

MEGACURIE мегакюри.

One million curies. *See* **Curie.**

MEGATON ENERGY количество энергии, освобождающейся при ядерном взрыве, эквивалентное количеству энергии, выделяющейся при взрыве 1 млн. тонн тротила.

The energy of a nuclear (or atomic) explosion which is equivalent to 1,000,000 tons (or 1,000 kilotons) of TNT, i. e., 10^{15} calories or 4.2×10^{22} ergs. *See* **TNT equivalent.**

MEV *See* **million electron volt.**

MICROCURIE микрокюри.

A one-millionth part of a curie. *See* **Curie.**

MICRON микрон.

A one-millionth part of a meter, it is roughly four one-hundred-thousandths (4×10^{-5}) of an inch.

MICROSECOND микросекунда.

A one-millionth part of a second.

MILLION ELECTRON VOLT мегаэлектрон-вольт (Мэв).

A unit of energy commonly used in nuclear physics. It is equivalent to $1\cdot6\cdot10^{-6}$ erg. Approximately 200 Mev of energy are produced for every nucleus that undergoes fission. *See* **electron volt.**

MILLIREM одна тысячная часть БРЭ (биологического рентген-эквивалента).

A one-thousandth part of a rem. *See* **rem.**

MILLIROENTGEN миллирентген.

A one-thousandth part of a roentgen. *See* **roentgen.**

MILLISECOND миллисекунда.

A one-thousandth part of a second.

MINIMUM NORMAL BURST ALTITUDE минимальная высота взрыва.

The altitude above terrain below which air defense nuclear warheads normally are not detonated.

MINIMUM SAFE DISTANCE минимальное безопасное расстояние.

Minimum safe distance is the sum of the radius of safety and the buffer distance.

MIRROR POINT фокусная точка.

A point at which a charged particle, moving (in a spiral path) along the lines of a magnetic field, is reflected back as it enters a stronger magnetic field region. The actual location of the mirror point depends on the direction and energy of motion of the charged particle and the ratio of the magnetic field strengths. As a result, only those particles satisfying the requirements of the existing situation are reflected.

MONITORING радиационная разведка.
The procedure or operation of locating and measuring radioactive contamination by means of survey instruments which can detect and measure (as dose rates) ionizing radiations. The individual performing the operation is called a monitor.

N

NEGATIVE PHASE фаза разрежения (фаза отрицательного давления).
See **shock wave.**
NEUTRON нейтрон.
A neutral particle, i. e., with no electrical charge, of approximately unit mass, present in all atomic nuclei, except those of ordinary (light) hydrogen. Neutrons are required to initiate the fission process, and large numbers of neutrons are produced by both fission and fusion reactions in nuclear (or atomic) explosions.
NEUTRON FLUX нейтронный поток.
The product of the neutron density (number per cubic centimeter) and the neutron velocity; the flux is expressed as neutrons per square centimeter per second. It is numerically equal to the total number of neutrons passing, in all directions, through a sphere of 1 square centimeter cross sectional area per second.
NEVADA TEST SITE испытательный полигон в штате Невада (США).
An area within the continental United States used for nuclear (or atomic) tests. It is located northwest of Las Vegas, Nevada, within the boundaries of the Las Vegas Bombing and Gunnery Range.
NOMINAL ATOMIC BOMB номинальная атомная бомба.
A term, now becoming obsolete, formerly used to describe an atomic weapon with an energy release equivalent to 20 kilotons (i. e., 20,000 tons) of TNT. This was approximately the energy yield of the bombs exploded over Japan and in the Bikini tests of 1946.
NUCLEAR PARITY равенство сил в отношении ядерного оружия.
A condition at a given point in time when opposing forces possess nuclear offensive and defensive systems approximately equal in overall combat effectiveness.
NUCLEAR RADIATION ядерная радиация.
Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the weapons standpoint, are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true; X-rays, for example, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atomic nuclei. *See* **ionizing radiation, X-rays.**
NUCLEAR ROUND ядерный боеприпас.
Consists of a nuclear weapon (warhead section) and the associated missile and/or propellant required to deliver the weapon on a target.
NUCLEAR STRIKE WARNING оповещение об атомном нападении.
A warning of impending friendly nuclear attack.

NUCLEAR WEAPON (or BOMB) ядерное оружие (бомба).

A general name given to any weapon in which the explosion results from the energy released by reactions involving atomic nuclei, either fission or fusion or both. Thus, the A- (or atomic) bomb and the H- (or hydrogen) bomb are both nuclear weapons. It would be equally true to call them atomic weapons, since it is the energy of atomic nuclei that is involved in each case. However, it has become more-or-less customary, although it is not strictly accurate, to refer to weapons in which all the energy results from fission as A-bombs or atomic bombs. In order to make a distinction, those weapons in which part, at least, of the energy results from thermonuclear (fusion) reactions among the isotopes of hydrogen have been called H-bombs or hydrogen bombs.

NUCLEAR WEAPON EMPLOYMENT TIME время, необходимое на доставку ядерного боеприпаса.

The time required for delivery of a nuclear weapon after the decision to fire has been made.

NUCLEAR WEAPONS ALLOCATION распределение ядерного оружия между соединениями.

Designation by a higher authority of numbers and types of nuclear weapons which a commander may expend when nuclear warfare is authorized. The allocation is usually stated for a definite period of operation. It does not indicate necessarily physical possession or custody.

NUCLEAR WEAPONS SUBALLOCATIONS распределение ядерного оружия между частями (подразделениями).

The action taken by component commanders in allocating nuclear weapons to subordinate commanders in accordance with assigned portions of theater missions.

NUCLEAR YIELDS мощность ядерного боеприпаса, тротиловый эквивалент.

Nuclear yields are categorized as: very low — less than one kiloton; low — one kiloton to 10 kilotons; medium — over 10 kilotons to 50 kilotons; high — over 50 kilotons to 500 kilotons; very high — over 500 kilotons. *See* **yield.**

NUCLEUS (or ATOMIC NUCLEUS) атомное ядро.

The small, central, positively charged region of an atom which carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which is a single proton, all atomic nuclei contain both protons and neutrons. The number of protons determines the total positive charge, or atomic number; this is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons, called the mass number, is closely related to the mass (or weight) of the atom. The nuclei of isotopes of a given element contain the same number of protons, but different numbers of neutrons. They thus have the same atomic number, and so are the same element, but they have different mass numbers (and masses). The nuclear properties, e. g., radioactivity, fission, neutron capture, etc., of an isotope of a given element are determined by both the number of neutrons and the number of protons. *See* **atom, element, isotope, neutron, proton,**

О

ON CALL по заявке (вызову).

The term used to signify that a prearranged concentration, air strike or barrage may be called for.

OPERATIONAL MISSILE ракета, принятая на вооружение.

A missile which has been accepted by the using services for tactical and strategic use.

OVERPRESSURE избыточное давление.

The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast) wave from an explosion. The variation of the overpressure with time depends on the energy yield of the explosion, the distance from the point of burst, and the medium in which the weapon is detonated. The peak overpressure is the maximum value of the overpressure at a given location and is generally experienced at the instant the shock (or blast) wave reaches that location. *See* **shock wave**.

П

PAIR PRODUCTION парное рождение частиц.

The process whereby a gamma-ray (or X-ray) photon, with energy in excess of 1.02 Mev, in passing near the nucleus of an atom is converted into a positive electron and a negative electron. As a result, the photon ceases to exist. *See* **photon**.

PHOTOELECTRIC EFFECT фотоэлектрический эффект.

The process whereby a gamma-ray (or X-ray) photon, with energy somewhat greater than that of the binding energy of an electron in an atom, transfers all its energy to the electron which is consequently removed from the atom. Since it has lost all its energy, the photon ceases to exist. *See* **photon**.

PHOTON фотон.

A unit or "particle" of electromagnetic radiation, possessing a quantum of energy which is characteristic of the particular radiation.

PLUME полый столб *(султан)*.

See **column**.

POINT TARGET точечная цель.

A target which requires the accurate placement of bombs or fire.

POSITIVE PHASE фаза положительного давления *(фаза сжатия)*.

See **shock wave**.

PRECURSOR предвестник *(начальный участок ударной волны)*.

An air pressure wave which moves ahead of the main blast wave for some distance as a result of a nuclear (or atomic) explosion of appropriate yield and low burst height over a heat-absorbing (or dusty) surface. The pressure at the precursor front increases more gradually than in a true (or ideal) shock wave, so that the behavior in the precursor region is said to be nonideal. *See* **blast wave, shock front, shock wave**.

PREPARED MISSILE ракета, подготовленная для боевого применения.

A tactical missile assembled and serviceable assigned to a combat unit requiring only target designation programing and launching to effect combat usage.

PRONE SHELTER укрытие для солдат в положении лежа.

Trench that is deep enough to protect a man lying flat on it from small arms fire and from ground burst bombs and artillery shell. A prone shelter gives little or no protection against fire from overhead including airburst shell.

PROTON протон.

A particle of mass (approximately) unity carrying a unit positive charge; it is identical physically with the nucleus of the ordinary (light) hydrogen atom. All atomic nuclei contain protons. *See* **nucleus.**

PROXIMITY FUSE дистанционный взрыватель.

A fuse designed to detonate a charge when activated by an external influence in the close vicinity of a target.

Q

QUANTUM квант.

See **photon.**

R

RAD рад.

A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of nuclear (or ionizing) radiation per gram of the absorbing material or tissue.

RADIANT EXPOSURE количество поглощенной энергии светового излучения.

The total amount of thermal radiation energy received per unit area of exposed surface; it is usually expressed in calories per square centimeter.

RADIATION INJURY (or **SYNDROME)** радиационное поражение (синдром).

See **syndrome (radiation).**

RADIATION PROTECTION GUIDE указание по радиационной защите.

The total amount of ionizing radiation dose over certain periods of time which may be permitted to persons whose occupation involves exposure to such radiation. It is equivalent to what was formerly called the Maximum Permissible Exposure (or MPE).

RADIATION SITUATION MAP карта радиационной обстановки.

A map depicting the current and predicted radiation situation in the area of interest.

RADIOACTIVE (or **ATOMIC) CLOUD** радиоактивное облако (взрыва).

An all-inclusive term for the mixture of hot gases, smoke, dust, and other particulate matter from the weapon itself and from the environment, which is carried aloft in conjunction with the rising fireball produced by the detonation of a nuclear (or atomic) weapon.

RADIOACTIVITY радиоактивность.

The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an (unstable) isotope. As a result of this emission the radioactive isotope is converted (or decays) into the isotope of a different (daughter) element which may (or may not) also be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (non-radioactive) end product is formed.

RADIOACTIVITY CONCENTRATION GUIDE указания о допустимой концентрации радиоактивности.

The amount of any specified radioisotope that is acceptable in air and water for continuous consumption. It is equivalent to what was formerly called the Maximum Permissible Concentration (or MPC).

RADIOLOGICAL DEFENSE защита от поражения радиоактивным излучением.

Incompasses defensive measures to be taken against the radiation hazards resulting from the employment of nuclear and radiological weapons.

RADIOLOGICAL MONITORING радиационная разведка; дозиметрический контроль.

The detection and/or measurement of radioactive contamination on area, structures, personnel, equipment and supplies.

RADIOLOGICAL OPERATIONS боевое применение радиологического оружия.

Employment of radioactive materials or radiation producing devices to cause casualties or restrict the use of terrain. Includes the intentional employment of fallout from nuclear weapons.

RADIOLOGICAL SURVEY радиационная разведка.

The directed effort to determine the distribution and dose rates of radiation in an area.

RADIOLOGICAL SURVEY INSTRUMENT дозиметрический прибор.

Apparatus for measuring radiological contamination in an area.

RADIUS OF DAMAGE радиус зоны поражения и разрушения.

That distance from ground zero at which a particular target has a 50 percent probability of sustaining a special level of damage.

RADIUS OF SAFETY радиус зоны безопасного удаления.

The horizontal distance from ground zero beyond which the weapons effects on friendly troops are acceptable.

RBE *See* **relative biological effectiveness.**

RCG *See* **radioactivity concentration guide.**

READY MISSILE реактивный снаряд, находящийся в состоянии полной боевой готовности, боеготовая ракета.

A tactical missile possessed by a combat unit mounted on a launcher requiring only a fire command to effect combat usage.

REFLECTED PRESSURE давление отражения.

The total pressure which results instantaneously at the surface when a shock (or blast) wave traveling in one medium strikes another medium, e. g., at the instant when the front of a blast wave in air strikes the surface of an object or structure.

REFLECTION FACTOR коэффициент отражения.

The ratio of the total (reflected) pressure to the incident pressure when a shock (or blast) wave traveling in one medium strikes another.

RELATIVE BIOLOGICAL EFFECTIVENESS относительная биологическая эффективность.

The ratio of the number of rads of gamma (or X-) radiation of a certain energy which will produce a specified biological effect to the number of rads of another radiation required to produce the same effect is the relative biological effectiveness of this latter radiation.

REM *See* **roentgen equivalent man.**

REP *See* **roentgen equivalent physical.**

RESIDUAL NUCLEAR RADIATION остаточная ядерная радиация.

Nuclear radiation, chiefly beta particles and gamma rays, which persists for some time following a nuclear (or atomic) explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout, and to some extent by earth and water constituents, and other materials, in which radioactivity has been induced by the capture of neutrons. *See* **fallout, induced radioactivity, initial nuclear radiation.**

ROENTGEN рентген.

A unit of exposure dose of gamma (or X-) radiation. It is defined precisely as the quantity of gamma (or X-) radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit quantity of electricity of either sign. From the accepted value (34 electron volts) for the energy lost by an electron in producing a positive-negative ion pair in air, it is estimated that 1 roentgen of gamma (or X-) radiation, would result in the absorption of about 87 ergs of energy per gram of air.

ROENTGEN EQUIVALENT MAN (or **MAMMAL**) биологический эквивалент рентгена.

A unit of biological dose of radiation. The number of rems of radiation is equal to the number of rads absorbed multiplied by the RBE of the given radiation (for a specified effect). *See* **rad, RBE.**

ROENTGEN EQUIVALENT PHYSICAL физический эквивалент рентгена.

A unit of absorbed dose of radiation now being replaced by the rad. Basically, the rep was intended to express the amount of energy absorbed per gram of soft tissue as a result of exposure to 1 roentgen of gamma (or X-) radiation. This is estimated to be about 97 ergs, although the actual value depends on certain experimental data which are not precisely known. The rep is thus defined, in general, as the dose of any ionizing radiation which results in the absorption of about 97 ergs of energy per gram of soft tissue. For soft tissue, the rep and the rad are essentially the same. *See* **rad, roentgen.**

S

SAL *See* **special ammunition load.**

SALTED WEAPON „грязное" ядерное оружие (бомба).

A nuclear weapon which has, in addition to its normal components, certain elements or isotopes which capture neutrons at the time of the explosion and produce radioactive products over and above the usual radioactive weapon debris.

SASP *See* **special ammunition supply point.**

SCALING LAW закон подобия.

A mathematical relationship which permits the effects of a nuclear (or atomic) explosion of given energy yield to be determined as a function of distance from the explosion (or from ground zero), provided the corresponding effect is known as a function of distance for a reference explosion, e. g., of 1-kiloton energy yield.

SCATTERING рассеивание.

The diversion of radiation, either thermal or nuclear, from its

original path as a result of interactions (or collisions) with atoms, molecules, or larger particles in the atmosphere or other medium between the source of the radiations, e. g., a nuclear (or atomic) explosion, and a point at some distance away. As a result of scattering, radiations (especially gamma rays and neutrons) will be received at such a point from many directions instead of only from the direction of the source.

SCHEDULED FIRES плановые (атомные) удары.

Prearranged fires which are to be executed it a specific time or upon occurrence of specified event in the action.

SHEAR (WIND) градиент ветра по высоте.

Unless the term "velocity shear" is used, wind shear refers to differences in direction (directional shear) of the wind at different altitudes. It is commonly expressed in degrees per thousand feet (kilofoot).

SHEAR WALL несущая стена.

A wall (or partition) designed to take a load in the direction of the plane of the wall, as distinct from lateral loads perpendicular to the wall. Shear walls may be designed to take lateral loads as well.

SHIELDING экранирование.

Any material or obstruction which absorbs radiation and thus tends to protect personnel or materials from the effects of a nuclear (or atomic) explosion. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed for nuclear radiation shielding.

SHOCK FRONT (or **PRESSURE FRONT**) фронт ударной волны.

The fairly sharp boundary between the pressure disturbance created by an explosion (in air, water, or earth) and the ambient atmosphere, water, or earth, respectively. It constitutes the front of the shock (or blast) wave.

SHOCK WAVE ударная волна.

A continuously propagated pressure pulse (or wave) in the surrounding medium which may be air, water, or earth, initiated by the expansion of the hot gases produced in an explosion. A shock wave in air is generally referred to as a blast wave, because it resembles and is accompanied by strong, but transient, winds. The duration of a shock (or blast) wave is distinguished by two phases. First there is the positive (or compression) phase during which the pressure rises very sharply to a value that is higher than ambient and then decreases rapidly to the ambient pressure. The positive phase for the dynamic pressure is somewhat longer than for overpressure, due to the momentum of the moving air behind the shock front. The duration of the positive phase increases and the maximum (peak) pressure decreases with increasing distance from an explosion of given energy yield. In the second phase, the negative (or suction) phase, the pressure falls below ambient and then returns to the ambient value. The duration of the negative phase is approximately constant throughout the blast wave history and may be several times the duration of the positive phase. Deviations from the ambient pressure during the negative phase are never large and they decrease with increasing distance from the explosion.

SPECIAL AMMUNITION ALLOCATION специальные боеприпасы, выделяемые подразделению (части) на определенный период.

A specific number of complete rounds of special ammunition authorized for expenditure by a commander during a specified period of time or phase of an operation.

SPECIAL AMMUNITION LOAD запас специальных боеприпасов в подразделении (части) доставки.

The specific quantity of special ammunition to be carried by a delivery unit. The establishment and replacement of this load after each expenditure is a command decision and is dependent upon the mission, the tactical and logistical situation and the capability of this unit to transport and utilize the load. It may vary from day to day and among similar delivery units.

SPECIAL AMMUNITION STOCKAGE запас специальных боеприпасов.

The specific quantity of various special ammunition items to be stocked in an ordnance unit or installation. It may vary from day to day and among similar ordnance units.

SPECIAL AMMUNITION SUPPLY POINT пункт снабжения специальными боеприпасами.

A mobile supply point where special ammunition is stored and issued to delivery units.

SPECIAL WEAPONS специальное оружие.

A term sometimes used to indicate weapons grouped for special procedures for security or other reasons. Specific terminology (e. g. nuclear weapons, guided missiles) is preferable.

SPRAY DOME купол.

See **dome.**

STANDING OPERATING PROCEDURE постоянно действующая инструкция.

A set of instructions covering those features of operations which lend themselves to a definite or standardized procedure without loss of effectiveness. The procedure is applicable unless prescribed otherwise in a particular case. Thus the flexibility necessary in special situations is retained.

STOCKPILE склады специальных боеприпасов.

Stores of special ammunition usually major assemblies of nuclear weapons (both nuclear and nonnuclear).

STOCKPILE TO TARGET SEQUENCE последовательность продвижения ракеты от момента изготовления до момента падения на цель.

The order and permutation of events involved in acceptance, storage, storage monitoring, assembly, testing and transportation of nuclear warhead section, nuclear projectile or atomic demolition munition. It describes this flow of materiel in all natural logistic and operational environments from production to destination on target.

STRATOSPHERE стратосфера.

A relatively stable layer of the atmosphere between the tropopause and a height of about 30 miles in which the temperature changes very little (in polar and temperate zones) or increases (in the tropics) with increasing altitudes. In the stratosphere clouds of water never form and there is practically no convection. *See* **tropopause, troposphere.**

SUBKILOTON WEAPON оружие (ядерное) докилотонной мощности.

A nuclear weapon producing a yield below one kiloton.

SUBSURFACE BURST подземный (подводный) взрыв.

See **underground burst, underwater burst.**

SUPERCRITICAL сверхкритический.

A term used to describe the state of a given fission system when the quantity of fissionable material is greater than the critical mass under the existing conditions. A highly supercritical system is essential for the production of energy at a very rapid rate so that an explosion may occur. *See* **critical mass.**

SURFACE BURST наземный взрыв.

The explosion of a nuclear (or atomic) weapon at the surface of the land or water or at a height above the surface less than the radius of the fireball at maximum luminosity (in the second thermal pulse). An explosion in which the weapon is detonated actually on the surface (or within 5 $W^{0.3}$ feet, where W is the explosion yield in kilotons, above or below the surface) is called a contact surface burst or a true surface burst. *See* **air burst.**

SURFACE ZERO эпицентр взрыва.

See **ground zero.**

SURGE (or **SURGE PHENOMENA)** базисная волна.

See **base surge.**

SURVEY METER дозиметрический прибор.

A portable instrument, such as a Geiger counter or ionization chamber, used to detect nuclear radiation and to measure the dose rate. *See* **monitoring.**

SYNDROME (RADIATION) лучевой синдром.

The complex of symptoms characterizing the disease known as radiation injury, resulting from excessive exposure of the whole (or a large part) of the body to ionizing radiation. The earliest of these symptoms are nausea, vomiting, and diarrhea, which may be followed by loss of hair (epilation), hemorrhage, inflammation of the mouth and throat, and general loss of energy. In severe cases, where the radiation exposure has been relatively large, death may occur within two to four weeks. Those who survive 6 weeks after the receipt of a single dose of radiation may generally be expected to recover.

T

TACTICAL DAMAGE ASSESSMENT тактическая оценка разрушений и степени поражения.

A direct examination of an actual strike area by air observation, air photography or by direct ground observation.

TACTICAL MISSILE тактическая ракета.

A missile produced for combat use.

TACTICAL MISSILE INVENTORY общее количество тактических ракет.

The total number of existing tactical missiles held at all combat and support levels, including missiles in depots and in transit, basic loads and reserve stocks. Excludes missiles allocated for nontactical use.

TARGET ACQUISITION обнаружение и разведка цели; целеуказание.

The detection, identification and location of a target in sufficient detail to permit the effective employment of weapons.

TARGET ANALYSIS оценка цели, определение характера цели.

An examination of potential targets to determine military importance, priority of attack and weapons required, to obtain a desired level of damage or casualties.

TARGET OFFSET поправка на смещение цели.

Horizontal angle at the target between a line from the target to the observation post.

TARGET OF OPPORTUNITY выгодная (внезапно обнаруженная) цель.

A target visible to a surface or air vehicle or observer which is within the range of available weapons and against which fire has not been scheduled or requested.

TENTH-VALUE THICKNESS слой десятикратного ослабления.

The thickness of a given material which will decrease the amount (or dose) of gamma radiation to one-tenth of the amount incident upon it. Two tenth-value thicknesses will reduce the dose received by a factor of 10×10, i. e., 100, and so on. The tenth-value thickness of a given material depends on the gamma-ray energy, but for radiation of a particular energy it is roughly inversely proportional to the density of the material.

THERMAL ENERGY энергия светового излучения.

The energy emitted from the fireball as thermal radiation. The total amount of thermal energy received per unit area at a specified distance from a nuclear (or atomic) explosion is generally expressed in terms of calories per square centimeter. *See* **radiant exposure, thermal radiation, transmittance.**

THERMAL ENERGY YIELD (or **THERMAL YIELD)** доля энергии ядерного взрыва, приходящаяся на световое излучение.

The part of the total energy yield of the nuclear (or atomic) explosion which is received as thermal energy usually within a minute or less. In an air burst, the thermal energy is, on the average, about one-third of the total energy of the explosion. For a high-altitude burst, roughly one-fourth of the total yield is received as thermal energy at a distance within about a minute. The thermal energy may be expressed in calories, ergs, or in terms of the TNT equivalent.

THERMAL RADIATION световое излучение.

Electromagnetic radiation emitted (in two pulses from an air burst) from the fireball as a consequence of its very high temperature; it consists essentially of ultraviolet, visible, and infrared radiations. In the early stages first ultraviolet radiation predominates; in the second pulse, the temperatures are lower and most of the thermal radiation lies in the visible and infrared regions of the spectrum. From a high-altitude burst, the thermal radiation is emitted in a single short pulse.

THERMAL X-RAYS первичное световое излучение (излучение мягких рентгеновских лучей).

The electromagnetic radiation, mainly in the soft (low-energy) X-ray region, emitted by the extremely hot weapon debris in virtue of its extremely high temperature; it is also referred to as the pri-

mary thermal radiation. It is the absorption of this radiation by the ambient medium, accompanied by an increase in temperature, which results in the formation of the fireball which then emits thermal radiation. *See* **weapon debris, X-rays.**

THERMONUCLEAR термоядерный.

An adjective referring to the process (or processes) in which very high temperatures are used to bring about the fusion of light nuclei, such as those of the hydrogen isotopes (deuterium and tritium), with the accompanying liberation of energy. A thermonuclear bomb is a weapon in which part of the explosion energy results from thermonuclear fusion reactions. The high temperatures required are obtained by means of a fission explosion. *See* **fusion.**

THRESHOLD DETECTOR пороговый детектор.

An element (or isotope) in which radioactivity is induced only by the capture of neutrons having energies in excess of a certain threshold value characteristic of the element (or isotope). Threshold detectors are used to determine the neutron spectrum from a nuclear (or atomic) explosion, i. e., the number of neutrons in various energy ranges.

TIME OF ATTACK время начала наступления.

The hour at which the attack is to be launched. If the line of departure is prescribed it is the hour at which the line is to be crossed by the leading elements of attack.

TNT EQUIVALENT тротиловый эквивалент.

A measure of the energy released in the detonation of a nuclear (or atomic) weapon, or in the explosion of a given quantity of fissionable material, expressed in terms of the weight of TNT which would release the same amount of energy when exploded. The TNT equivalent is usually stated in kilotons or megatons. The basis of the TNT equivalence is that the explosion of 1 ton of TNT releases 10^9 calories of energy. *See* **kiloton energy, megaton energy, yield.**

TOLERANCE DOSE допустимая доза облучения.

The amount of radiation which may be received by an individual within a specified period with negligible results.

TRANSMITTANCE (ATMOSPHERIC) проводимость.

The fraction (or percentage) of the thermal energy received at a given location after passage through the atmosphere relative to that which would have been received at the same location if no atmosphere were present.

TRIPLE POINT тройная точка.

The intersection of the incident, reflected, and fused (or Mach) shock fronts accompanying an air burst. The height of the triple point above the surface, i. e., the height of the Mach stem, increases with increasing distance from a given explosion. *See* **Mach stem.**

TRITIUM тритий.

A radioactive isotope of hydrogen, having a mass of 3 units; it is produced in nuclear reactors by the action of neutrons on lithium nuclei.

TROPOPAUSE тропопауза.

The imaginary boundary layer dividing the stratosphere from the lower part of the atmosphere, the troposphere. The tropopause normally occurs at an altitude of about 25,000 to 45,000 feet in the polar and temperate zones, and at 55,000 feet in the tropics.

TROPOSPHERE тропосфера.

The region of the atmosphere immediately above the earth's surface and up to the tropopause in which the temperature falls fairly regularly with increasing altitude, clouds form, convection is active, and mixing is continuous and more or less complete.

TRUE SURFACE BURST наземный взрыв.

See **surface burst.**

TWO-W CONCEPT (2W CONCEPT) принцип двойного увеличения мощности при наземном взрыве.

The concept that the explosion of a weapon of energy yield W on the earth's surface produces blast phenomena identical to those produced by a weapon of twice the yield, i. e., 2W, burst in free air, i. e., away from any reflecting surface.

U

ULTRAVIOLET ультрафиолетовый.

Electromagnetic radiation of wave length between the shortest visible violet (about 3,850 Angstroms) and soft X-rays (about 100 Angstroms).

UNDERGROUND BURST подземный взрыв.

The explosion of a nuclear (or atomic) weapon with its center more than $5W^{0.3}$ feet, where W is the explosion yield in kilotons, beneath the surface of the ground. *See* **contained underground burst.**

UNDERWATER BURST подводный взрыв.

The explosion of a nuclear (or atomic) weapon with its center beneath the surface of the water.

V

VENTING выброс в атмосферу (радиоактивных газов).

The escape through the surface to the atmosphere of the gases and other residues formed in a subsurface explosion.

VISIBILITY RANGE (or **VISIBILITY**) предел видимости.

The horizontal distance (in kilometers or miles) at which a large dark object can just be seen against the horizon sky in daylight. The visibility is related to the clarity of the atmosphere, ranging from 170 miles (280 kilometers) for an exceptionally clear atmosphere to 0.6 mile or less (1.0 kilometer or less) for dense haze or fog.

W

WEAPON, ATOMIC (or **NUCLEAR**) атомное (ядерное) оружие.

See **nuclear weapon.**

WEAPON DEBRIS продукты взрыва.

The highly radioactive material, consisting of fission products,

various products of neutron capture, and uranium and plutonium that have escaped fission, remaining after the explosion.

WEAPON RESIDUE испарившиеся остатки ядерного боеприпаса.

The extremely hot, compressed gaseous residues formed at the instant of the explosion of a nuclear weapon. The temperature is several million degrees and the pressure is many millions of atmospheres.

WORLD-WIDE FALLOUT выпадение радиоактивных веществ в пределах всего земного шара.

See **fallout.**

X

X-RAYS рентгеновские лучи.

Electromagnetic radiations of high energy having wave lengths shorter than those in the ultraviolet region, i. e., less than 10^{-6} cm or 100 Angstroms. As generally produced by X-ray machines, they are bremsstrahlung resulting from the interaction of electrons of 1 kilo-electron volt or more energy with a metallic target.

Y

YIELD (or **ENERGY YIELD**) мощность (ядерного боеприпаса); тротиловый эквивалент.

The total effective energy released in a nuclear (or atomic) explosion. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested an nuclear radiation, thermal radiation, and shock (and blast) energy, the actual distribution being dependent upon the medium in which the explosion occurs (primarily) and also upon the type of weapon and the time after detonation.

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Secretos y Curiosidades de METRÓPOLIS (1927)
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Secretos y Curiosidades de METRÓPOLIS (1927)
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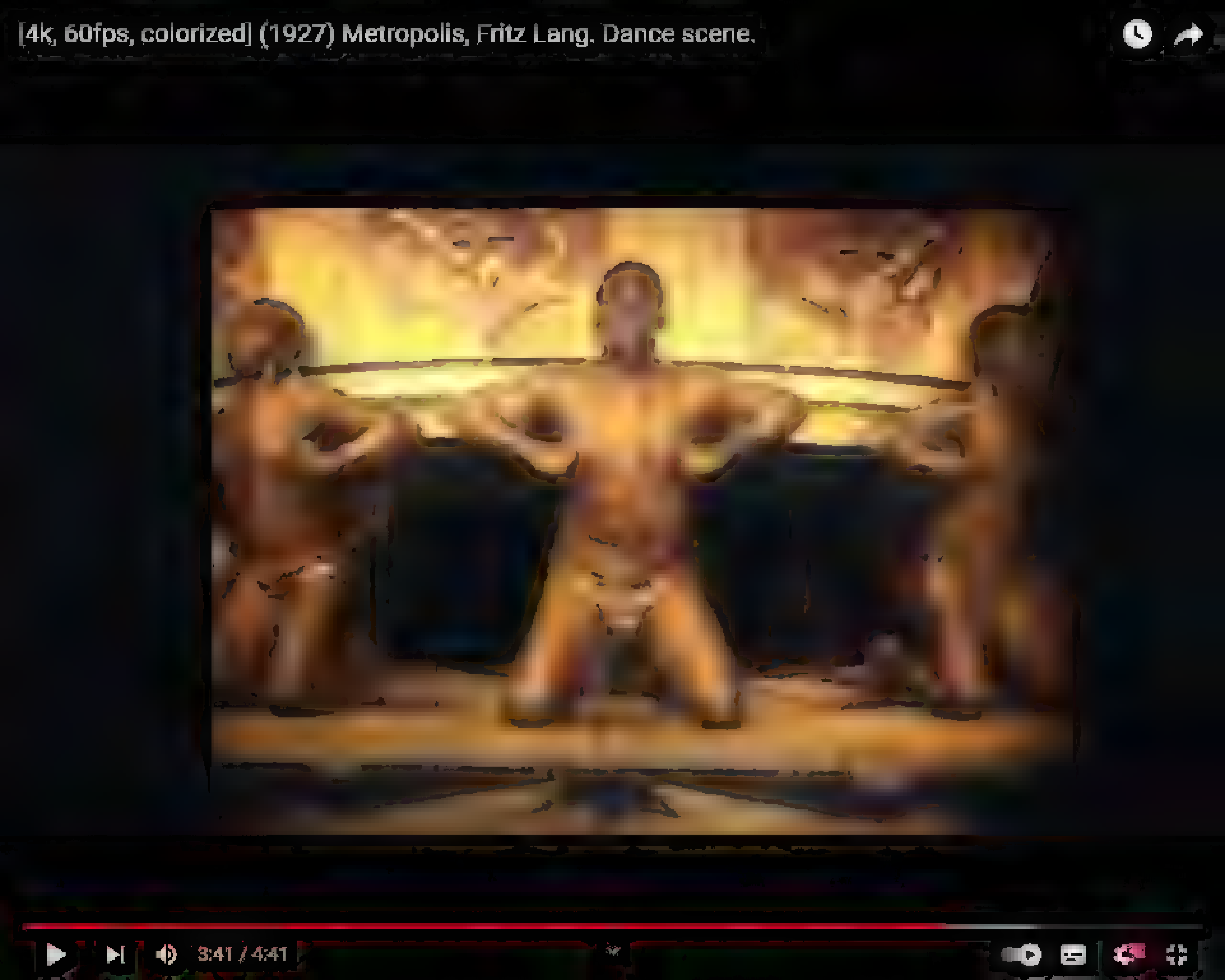
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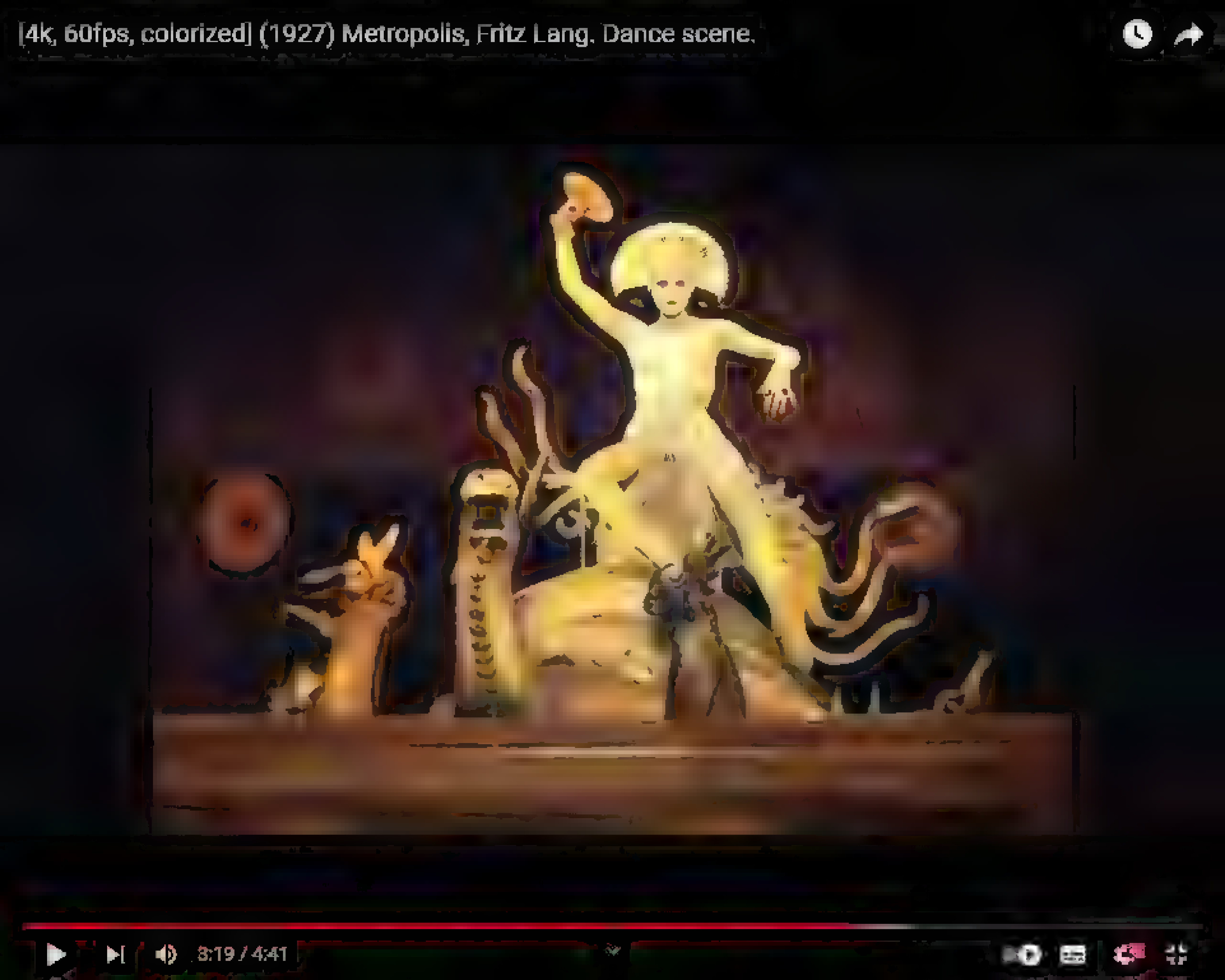
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[4k, 60fps, colorized] (1927) Metropolis, Fritz Lang. Dance scene.
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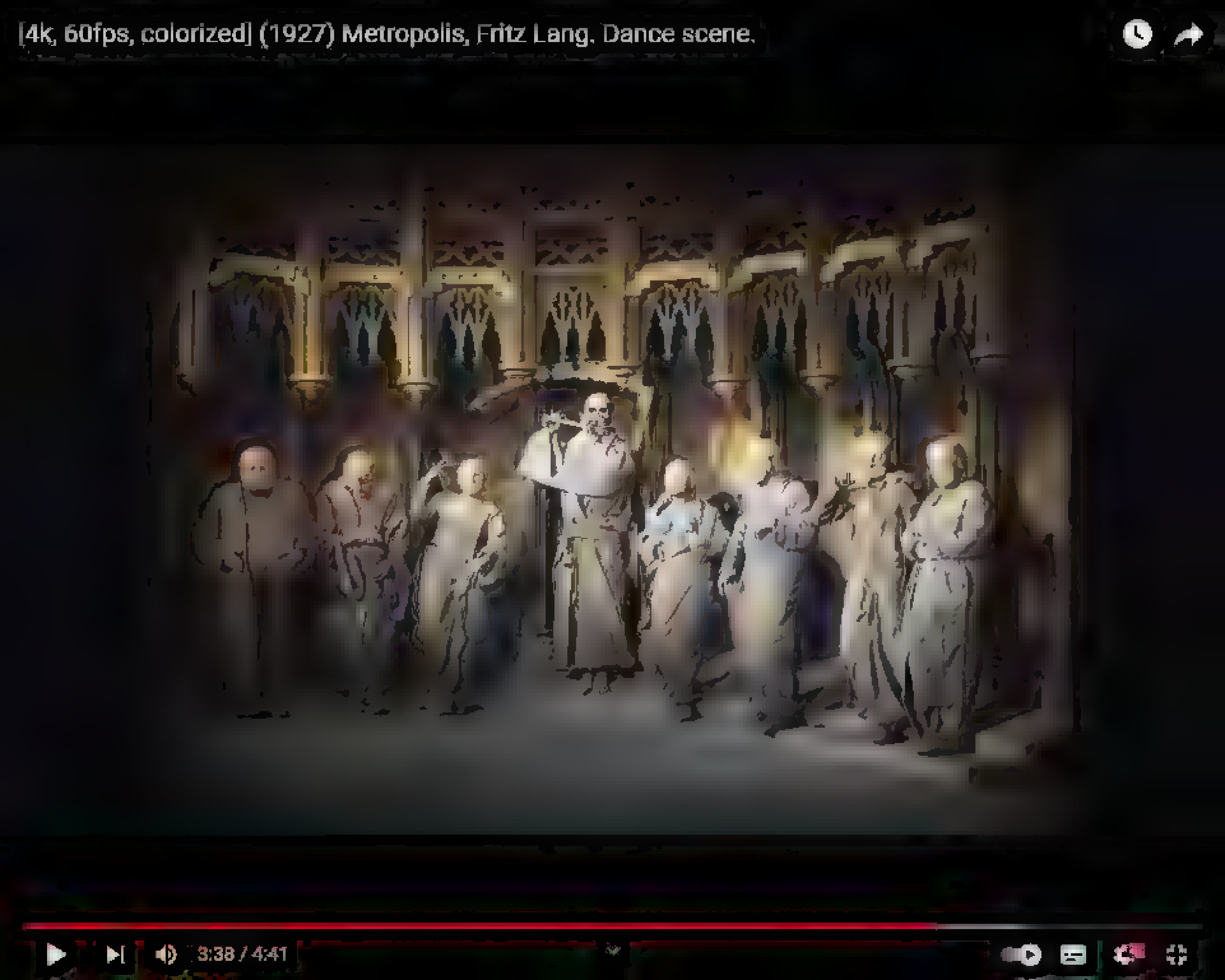
[4k, 60fps, colorized] (1927) Metropolis, Fritz Lang. Dance scene.
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NAPOLI – Museo Nazionale - Cibele in trono.


ROMA-Talia, musa della Commedia (Museo Vaticano)
TALIA

НИНА КУКОВЕРОВА

Ленинградскую пионерку Нину Куковерову Великая Отечественная война застала в деревушке Нечеперть. Как только в деревню вошел враг, Нина начала помогать партизанам. А потом и совсем ушла в лес к партизанам и стала разведчицей. Однажды ее послали в деревню Горы, где расположился карательный отряд. Нина притворилась нищенкой, попрошайкой, вошла в деревню и все подробно разглядела: где штаб, где арсенал, склад горючего. А ночью партизанский отряд разгромил фашистов, Нина указывала командиру все, что высмотрела днем. Много славных боевых дел совершила девочка, но однажды ушла в разведку и не вернулась... Нина Куковерова награждена медалью «Партизану Отечественной войны» 1-й степени и посмертно орденом Отечественной войны 1-й степени. В 74-й школе (ныне 34-я школа-интернат) Петроградского района Ленинграда на вечерней линейке пионерской дружины, куда Нина Куковерова зачислена навечно, первым называют ее имя.

НИНА КУКОВЕРОВА

САНЯ КОЛЕСНИКОВ

Санька. Саня. Сан Саныч... Так называли его боевые друзья. А в указах о награждении звучало неизменно гордо и весомо — Александр Александрович Колесников.

Этот отважный пионер — а победу он встретил четырнадцатилетним!— награжден орденом Славы III степени, орденом Отечественной войны I степени, медалями «За отвагу» — дважды, «За освобождение Варшавы», «За взятие Берлина», «За победу над Германией»...

Сане удавалось то, что оказывалось не под силу взрослым — добывал разведывательные данные буквально под носом у врага. Ему поручили выяснить, куда ведет стратегическая ветка железной дороги, та, что усиленно охранялась фашистами. Саня проследил весь ее путь, а потом, взбираясь на деревья, обозначил его кусками белой материи — с самолетов цель видна была отлично.

Однажды разведчики получили задание взорвать мост. Двое суток вели они наблюдение за охраной — не подобраться, казалось, было к мосту. И тогда Саня, прихватив взрывчатку, забрался в ящик под вагоном товарняка и, когда поезд приблизился к мосту, поджег бикфордов шнур. Внизу блеснула вода, Саня прыгнул — и тут же страшный взрыв сокрушил и состав, и мост.

Фашистский катер подобрал мальчика. Саню пытали, распяли на стене. Но разведчики отбили своего юного друга, героя. Потом был госпиталь, потом снова родной полк и победный путь до самого Берлина!

ЮТА БОНДАРОВСКАЯ

ЮТА БОНДАРОВСКАЯ

Ленинградскую пионерку Юту Бондаровскую Великая Отечественная война застала в деревне под Псковом. Фашисты заняли деревню, и Юта начала помогать партизанам: расклеивала листовки, носила взрывчатку, была связной. Когда полицаи напали на ее след, девочка совсем ушла в лес к партизанам. Ей было тринадцать лет, и ее хотели отправить на Большую землю, но она наотрез отказалась, Юта была отличной разведчицей. Прикинувшись нищенкой с сумой ходила она вокруг гитлеровцев, просила хлеба даже у них, высматривая и выведывая нужные партизанам сведения. С автоматом в руках она участвовала в боях. Когда партизаны соединились с Советской Армией, Юту опять хотели отправить в тыл, но она осталась с партизанами — освобождала Эстонию. Погибла Юта в жестоком бою у эстонского хутора Ростов. Юта Бондаровская посмертно награждена орденом Отечественной войны 1-й степени и медалью «Партизану Отечественной войны» 1-й степени.

IX - 16 — Scène de Comédie grecque (Sculpture antique).

Fernand Nathan, Editeur, Paris. — 1041